

LME49870 44V Single High Performance, High Fidelity Audio Operational Amplifier

Check for Samples: [LME49870](#)

FEATURES

- Easily Drives 600Ω Loads
- Optimized for Superior Audio Signal Fidelity
- Output Short Circuit Protection
- PSRR and CMRR Exceed 120dB (Typ)

APPLICATIONS

- High Quality Audio Amplification
- High Fidelity Preamplifiers, Phono Preamps, and Multimedia
- High Performance Professional Audio
- High Fidelity Equalization and Crossover Networks with Active Filters
- High Performance Line Drivers and Receivers
- Low Noise Industrial Applications Including Test, Measurement, and Ultrasound

KEY SPECIFICATIONS

- Power Supply Voltage Range: $\pm 2.5V$ to $\pm 22V$
- THD+N ($A_V = 1$, $V_{OUT} = 3V_{RMS}$, $f_{IN} = 1kHz$)
 - $R_L = 2k\Omega$: 0.00003% (Typ)
 - $R_L = 600\Omega$: 0.00003% (Typ)
- Input Noise Density: $2.7nV/\sqrt{Hz}$ (Typ)
- Slew Rate: $\pm 20V/\mu s$ (Typ)
- Gain Bandwidth Product: 55MHz (Typ)
- Open Loop Gain ($R_L = 600\Omega$): 140dB (Typ)
- Input Bias Current: 10nA (Typ)
- Input Offset Voltage: 0.1mV (Typ)
- DC Gain Linearity Error: 0.000009%

DESCRIPTION

The LME49870 is part of the ultra-low distortion, low noise, high slew rate operational amplifier series optimized and fully specified for high performance, high fidelity applications. Combining advanced leading-edge process technology with state-of-the-art circuit design, the LME49870 audio operational amplifier delivers superior audio signal amplification for outstanding audio performance. The LME49870 combines extremely low voltage noise density ($2.7nV/\sqrt{Hz}$) with vanishingly low THD+N (0.00003%) to easily satisfy the most demanding audio applications. To ensure that the most challenging loads are driven without compromise, the LME49870 has a high slew rate of $\pm 20V/\mu s$ and an output current capability of $\pm 26mA$. Further, dynamic range is maximized by an output stage that drives 2kΩ loads to within 1V of either power supply voltage and to within 1.4V when driving 600Ω loads.

The LME49870's outstanding CMRR (120dB), PSRR (120dB), and V_{OS} (0.1mV) give the amplifier excellent operational amplifier DC performance.

The LME49870 has a wide supply range of $\pm 2.5V$ to $\pm 22V$. Over this supply range the LME49870 maintains excellent common-mode rejection, power supply rejection, and low input bias current. The LME49870 is unity gain stable. This Audio Operational Amplifier achieves outstanding AC performance while driving complex loads with values as high as 100pF.

The LME49870 is available in 8-lead narrow body SOIC. Demonstration boards are available for each package.



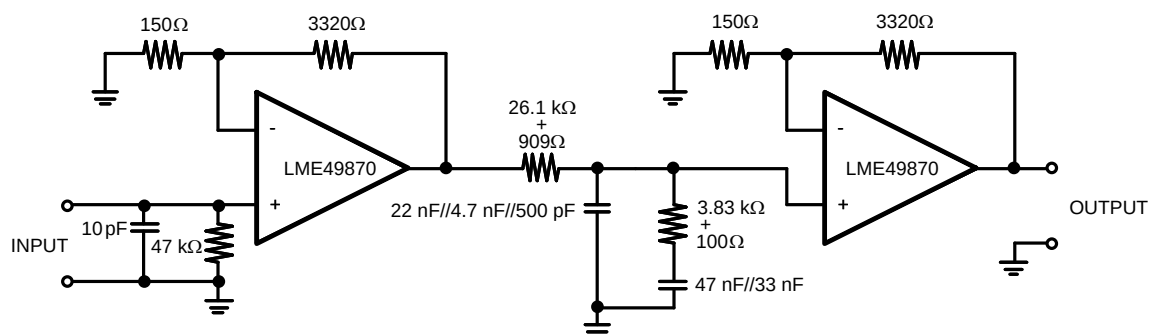
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TYPICAL APPLICATION



Note: 1% metal film resistors, 5% polypropylene capacitors

Figure 1. Passively Equalized RIAA Phono Preamplifier

CONNECTION DIAGRAM

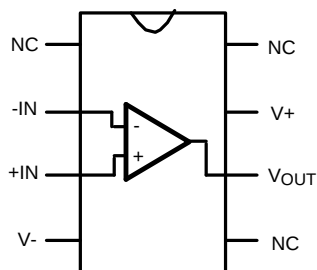


Figure 2. Package Number — D0008A



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ABSOLUTE MAXIMUM RATINGS⁽¹⁾⁽²⁾⁽³⁾

Power Supply Voltage ($V_S = V^+ - V^-$)		46V
Storage Temperature		-65°C to 150°C
Input Voltage		(V-) - 0.7V to (V+) + 0.7V
Output Short Circuit ⁽⁴⁾		Continuous
Power Dissipation		Internally Limited
ESD Rating ⁽⁵⁾		2000V
ESD Rating ⁽⁶⁾	Pins 1, 4, 7 and 8	200V
	Pins 2, 3, 5 and 6	100V
Junction Temperature		150°C
Thermal Resistance	θ_{JA} (SO)	145°C/W

- (1) "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the Absolute Maximum Ratings or other conditions beyond those indicated in the Recommended Operating Conditions is not implied. The Recommended Operating Conditions indicate conditions at which the device is functional and the device should not be operated beyond such conditions. All voltages are measured with respect to the ground pin, unless otherwise specified.
- (2) The Electrical Characteristics tables list ensured specifications under the listed Recommended Operating Conditions except as otherwise modified or specified by the Electrical Characteristics Conditions and/or Notes. Typical specifications are estimations only and are not ensured
- (3) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
- (4) The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX} , θ_{JA} , and the ambient temperature, T_A . The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$ or the number given in Absolute Maximum Ratings, whichever is lower.
- (5) Human body model, applicable std. JESD22-A114C.
- (6) Machine model, applicable std. JESD22-A115-A.

OPERATING RATINGS

Temperature Range ($T_{MIN} \leq T_A \leq T_{MAX}$)	$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$
Supply Voltage Range	$\pm 2.5\text{V} \leq V_S \leq \pm 22\text{V}$

ELECTRICAL CHARACTERISTICS FOR THE LME49870⁽¹⁾

The following specifications apply for $V_S = \pm 18V$ and $\pm 22V$, $R_L = 2k\Omega$, $R_{SOURCE} = 10\Omega$, $f_{IN} = 1kHz$, $T_A = 25^\circ C$, unless otherwise specified.

Symbol	Parameter	Conditions	LME49870		Units (Limits)
			Typical ⁽²⁾	Limit ⁽³⁾	
THD+N	Total Harmonic Distortion + Noise	$A_V = 1$, $V_{OUT} = 3V_{rms}$ $R_L = 2k\Omega$ $R_L = 600\Omega$	0.00003 0.00003	0.00009	% (max)
IMD	Intermodulation Distortion	$A_V = 1$, $V_{OUT} = 3V_{RMS}$ Two-tone, 60Hz & 7kHz 4:1	0.00005		%
GBWP	Gain Bandwidth Product		55	45	MHz (min)
SR	Slew Rate		± 20	± 15	V/ μs (min)
FPBW	Full Power Bandwidth	$V_{OUT} = 1V_{P-P}$, $-3dB$ referenced to output magnitude at $f = 1kHz$	10		MHz
t_s	Settling time	$A_V = -1$, 10V step, $C_L = 100pF$ 0.1% error range	1.2		μs
e_n	Equivalent Input Noise Voltage	$f_{BW} = 20Hz$ to $20kHz$	0.34	0.65	μV_{RMS} (max)
	Equivalent Input Noise Density	$f = 1kHz$ $f = 10Hz$	2.5 6.4	4.7	$nV/\sqrt{Hz}$ (max)
i_n	Current Noise Density	$f = 1kHz$ $f = 10Hz$	1.6 3.1		$pA/\sqrt{Hz}$
V_{OS}	Offset Voltage	$V_S = \pm 18V$	± 0.12		mV (max)
		$V_S = \pm 22V$	± 0.14	± 0.7	mV (max)
$\Delta V_{OS}/\Delta Temp$	Average Input Offset Voltage Drift vs Temperature	$-40^\circ C \leq T_A \leq 85^\circ C$	0.1		$\mu V/^\circ C$
PSRR	Average Input Offset Voltage Shift vs Power Supply Voltage	$V_S = \pm 18V$, $\Delta V_S = 24V$ ⁽⁴⁾ $V_S = \pm 22V$, $\Delta V_S = 30V$	120 120	110	dB (min)
I_B	Input Bias Current	$V_{CM} = 0V$	10	72	nA (max)
$\Delta I_{OS}/\Delta Temp$	Input Bias Current Drift vs Temperature	$-40^\circ C \leq T_A \leq 85^\circ C$	0.2		nA/ $^\circ C$
I_{OS}	Input Offset Current	$V_{CM} = 0V$	11	65	nA (max)
V_{IN-CM}	Common-Mode Input Voltage Range	$V_S = \pm 18V$	+17.1 -16.9		V (min) V (min)
		$V_S = \pm 22V$	+21.0 -20.8	(V+) – 2.0 (V-) + 2.0	V (min) V (min)
CMRR	Common-Mode Rejection	$V_S = \pm 18V$, $-12V \leq V_{cm} \leq 12V$	120		dB (min)
		$V_S = \pm 22V$, $-15V \leq V_{cm} \leq 15V$	120	110	dB (min)
Z_{IN}	Differential Input Impedance		30		k Ω
	Common Mode Input Impedance	$-10V < V_{cm} < 10V$	1000		M Ω

(1) "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the Absolute Maximum Ratings or other conditions beyond those indicated in the Recommended Operating Conditions is not implied. The Recommended Operating Conditions indicate conditions at which the device is functional and the device should not be operated beyond such conditions. All voltages are measured with respect to the ground pin, unless otherwise specified.

(2) Typical values represent most likely parametric norms at $T_A = +25^\circ C$, and at the Recommended Operation Conditions at the time of product characterization and are not ensured.

(3) Datasheet min/max specification limits are specified by test or statistical analysis.

(4) PSRR is measured as follows: For V_S , V_{OS} is measured at two supply voltages, $\pm 7V$ and $\pm 22V$, $PSRR = |20\log(\Delta V_{OS}/\Delta V_S)|$.

ELECTRICAL CHARACTERISTICS FOR THE LME49870⁽¹⁾ (continued)

The following specifications apply for $V_S = \pm 18V$ and $\pm 22V$, $R_L = 2k\Omega$, $R_{SOURCE} = 10\Omega$, $f_{IN} = 1kHz$, $T_A = 25^\circ C$, unless otherwise specified.

Symbol	Parameter	Conditions	LME49870		Units (Limits)
			Typical ⁽²⁾	Limit ⁽³⁾	
A_{VOL}	Open Loop Voltage Gain	$V_S = \pm 18V$ $-12V \leq V_{out} \leq 12V$ $R_L = 600\Omega$ $R_L = 2k\Omega$ $R_L = 10\Omega$	140 140 140		dB dB dB
		$V_S = \pm 22V$ $-15V \leq V_{out} \leq 15V$ $R_L = 600\Omega$ $R_L = 2k\Omega$ $R_L = 10\Omega$	140 140 140	125	dB dB dB
V_{OUTMAX}	Maximum Output Voltage Swing	$R_L = 600\Omega$ $V_S = \pm 18V$ $V_S = \pm 22V$	± 16.7 ± 20.4	± 19.0	V (min) V (min)
		$R_L = 2k\Omega$ $V_S = \pm 18V$ $V_S = \pm 22V$	± 17.0 ± 21.0		V (min) V (min)
		$R_L = 10k\Omega$ $V_S = \pm 18V$ $V_S = \pm 22V$	± 17.1 ± 21.0		V (min) V (min)
I_{OUT}	Output Current	$R_L = 600\Omega$ $V_S = \pm 20V$ $V_S = \pm 22V$	± 31 ± 37	± 30	mA (min) mA (min)
I_{OUT-CC}	Instantaneous Short Circuit Current		+53 –42		mA
R_{OUT}	Output Impedance	$f_{IN} = 10kHz$ Closed-Loop Open-Loop	0.01 13		Ω
C_{LOAD}	Capacitive Load Drive Overshoot	100pF	16		%
I_S	Total Quiescent Current	$I_{OUT} = 0mA$	5	6.5	mA (max)

TYPICAL PERFORMANCE CHARACTERISTICS

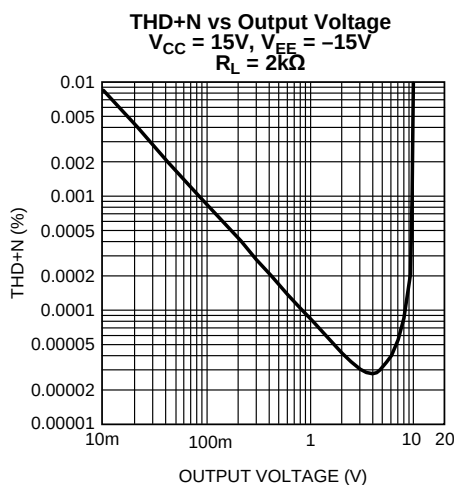


Figure 3.

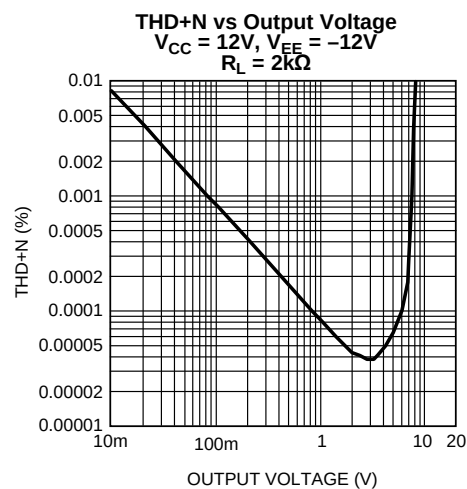


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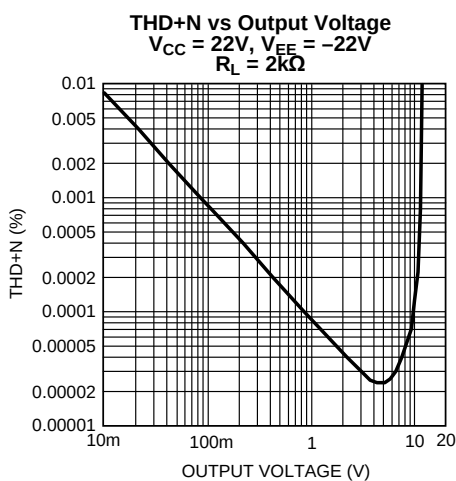


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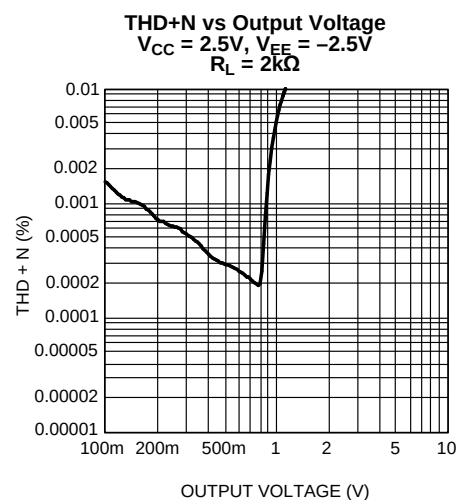


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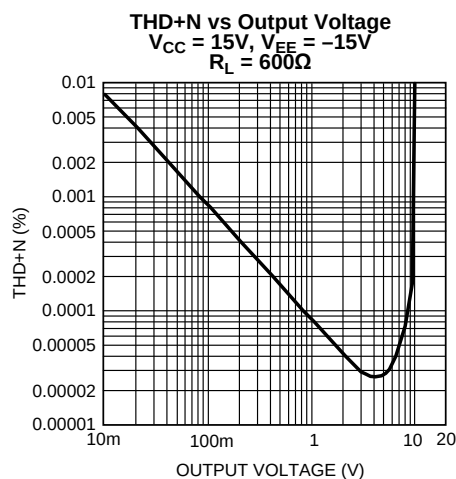


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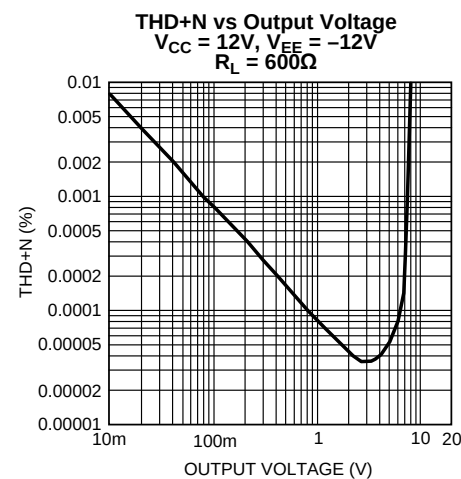


Figure 8.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

THD+N vs Output Voltage
 $V_{CC} = 22V$, $V_{EE} = -22V$
 $R_L = 600\Omega$

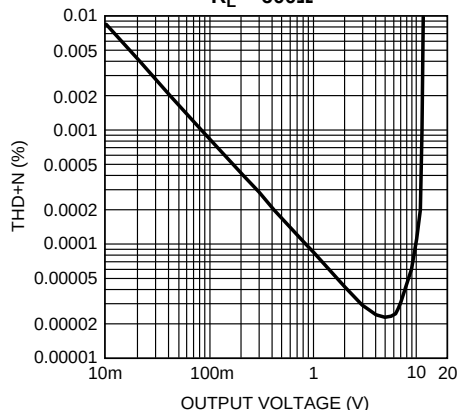


Figure 9.

THD+N vs Output Voltage
 $V_{CC} = 2.5V$, $V_{EE} = -2.5V$
 $R_L = 600\Omega$

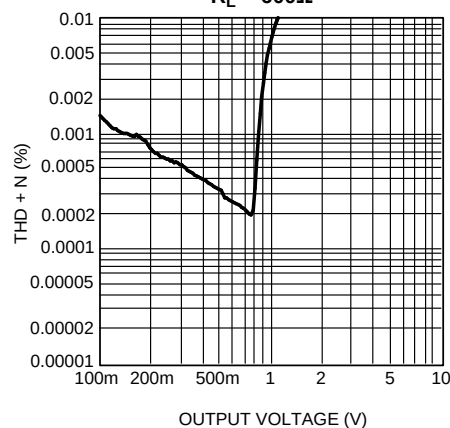


Figure 10.

THD+N vs Output Voltage
 $V_{CC} = 15V$, $V_{EE} = -15V$
 $R_L = 10k\Omega$

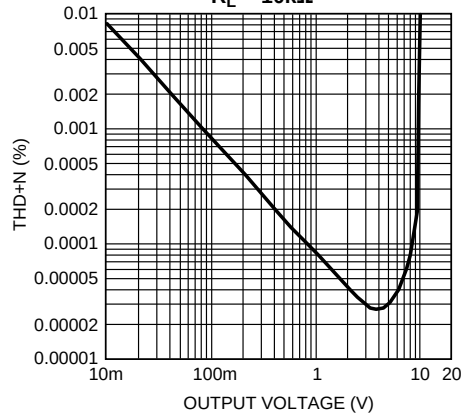


Figure 11.

THD+N vs Output Voltage
 $V_{CC} = 12V$, $V_{EE} = -12V$
 $R_L = 10k\Omega$

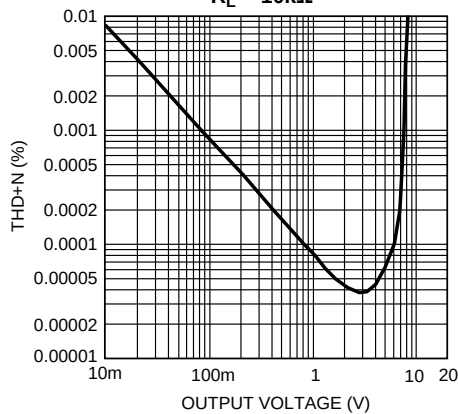


Figure 12.

THD+N vs Output Voltage
 $V_{CC} = 22V$, $V_{EE} = -22V$
 $R_L = 10k\Omega$

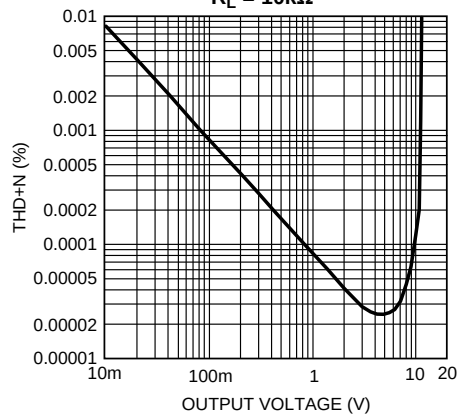


Figure 13.

THD+N vs Output Voltage
 $V_{CC} = 2.5V$, $V_{EE} = -2.5V$
 $R_L = 10k\Omega$

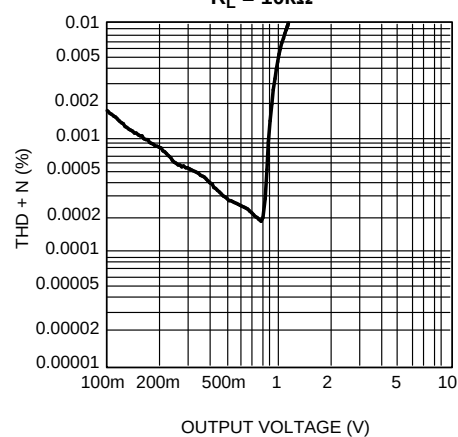
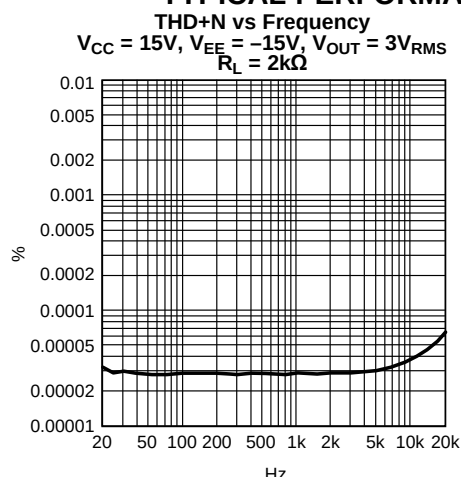
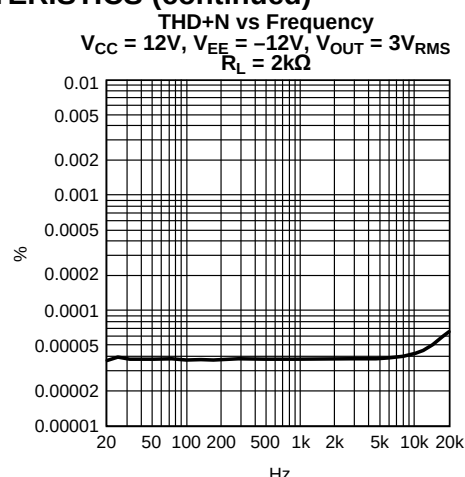
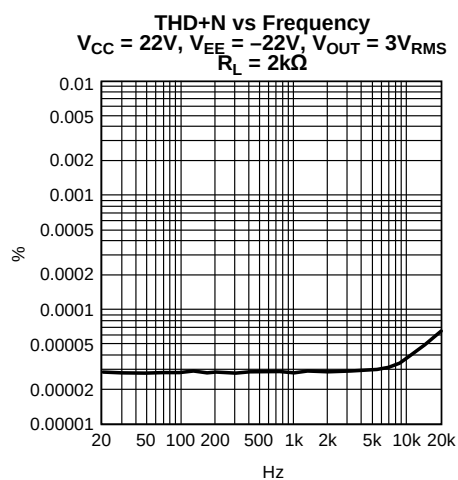
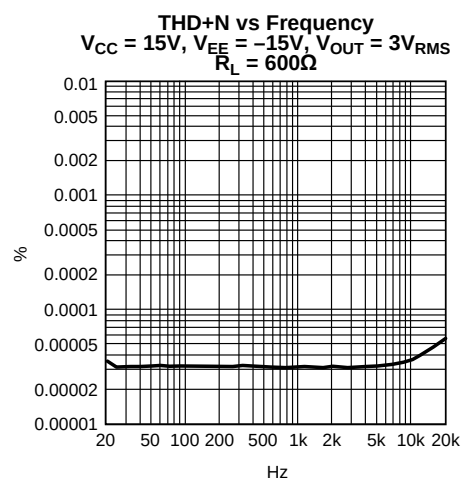
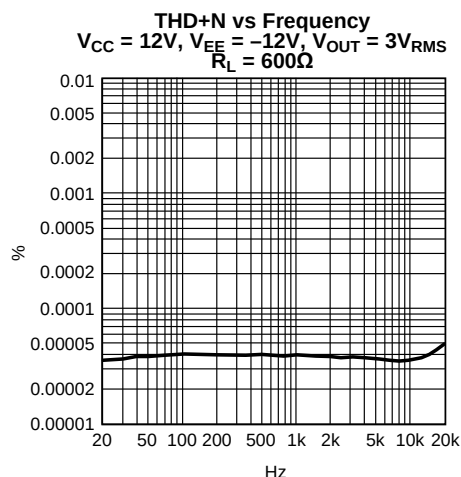
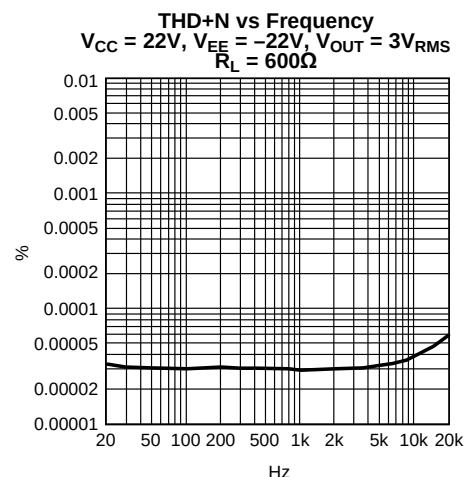


Figure 14.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)**Figure 15.****Figure 16.****Figure 17.****Figure 18.****Figure 19.****Figure 20.**

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

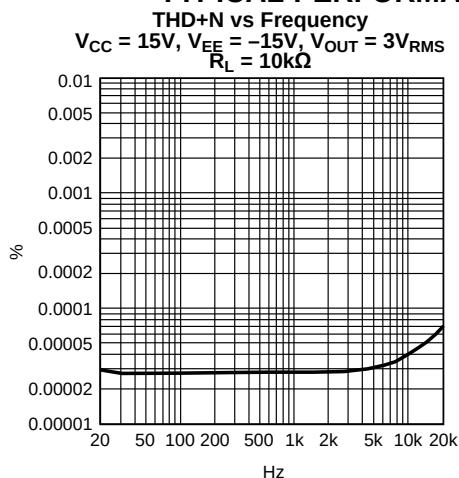


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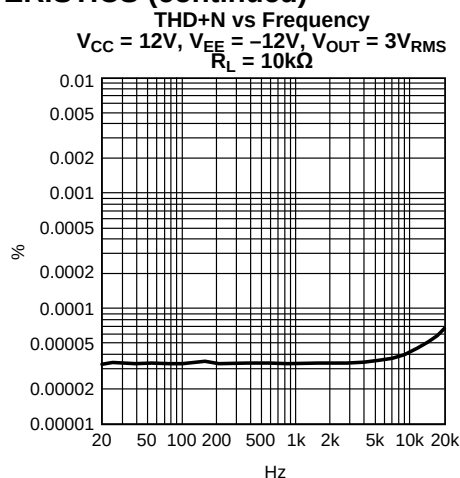


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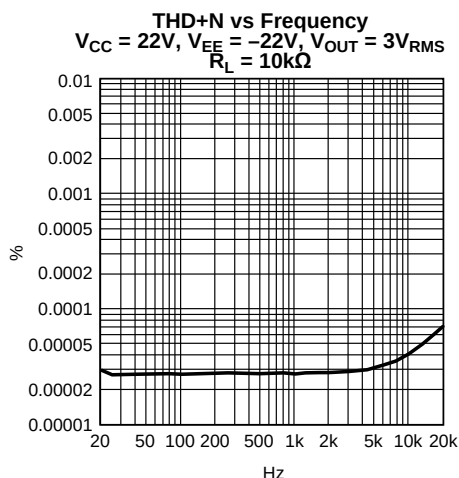


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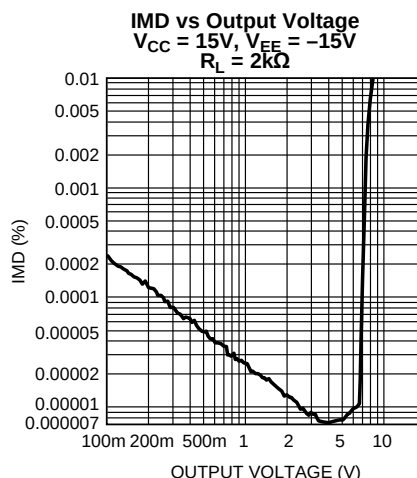


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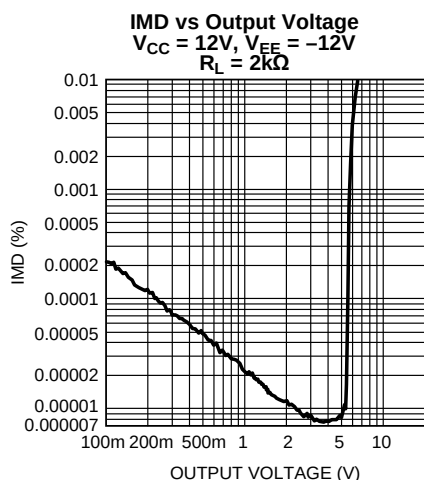


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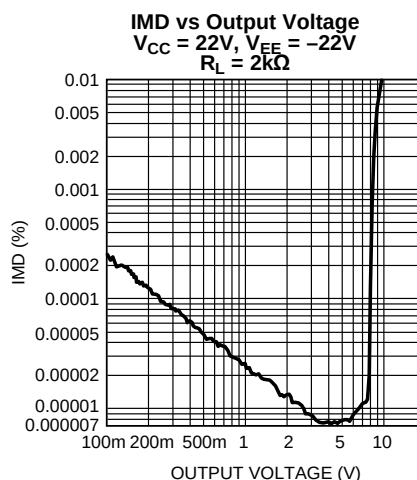
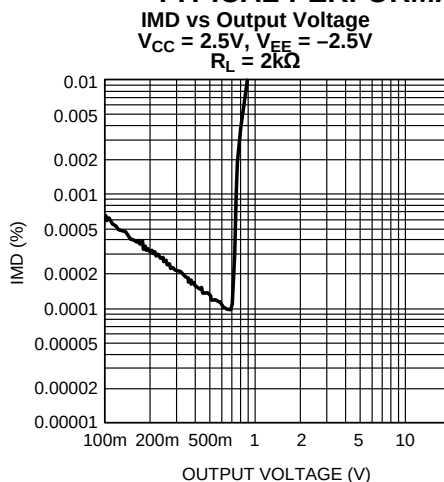
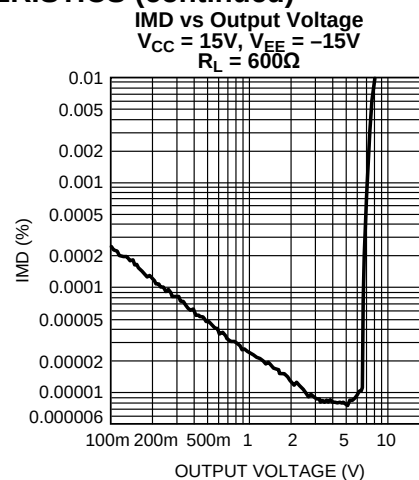
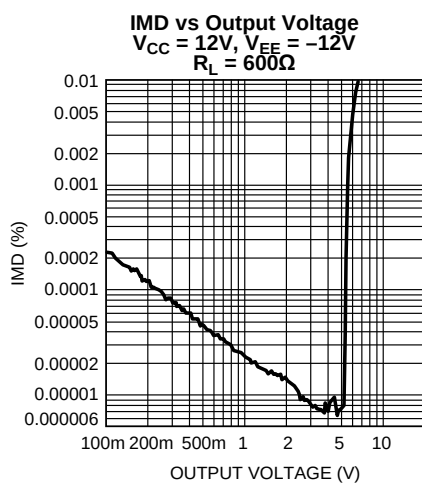
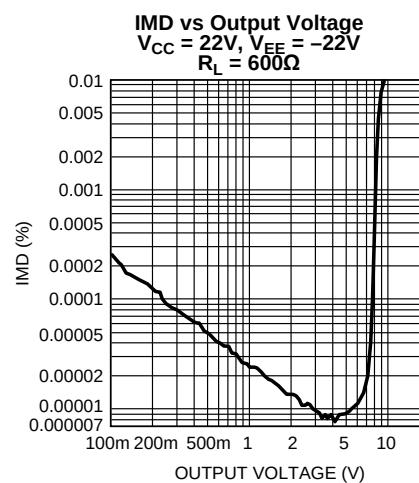
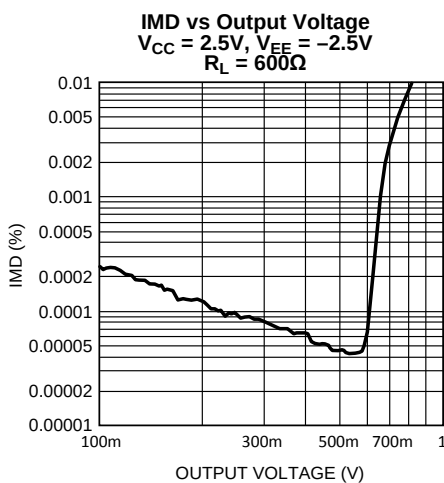
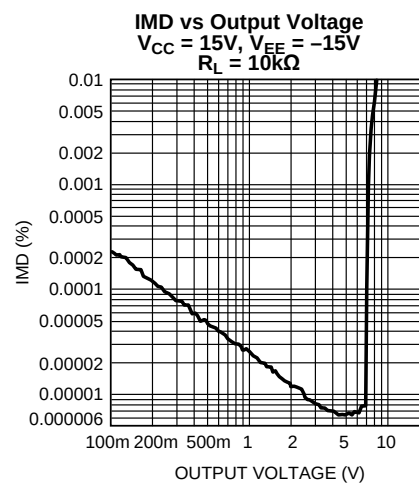


Figure 26.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)**Figure 27.****Figure 28.****Figure 29.****Figure 30.****Figure 31.****Figure 32.**

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

IMD vs Output Voltage
 $V_{CC} = 12V$, $V_{EE} = -12V$
 $R_L = 10k\Omega$

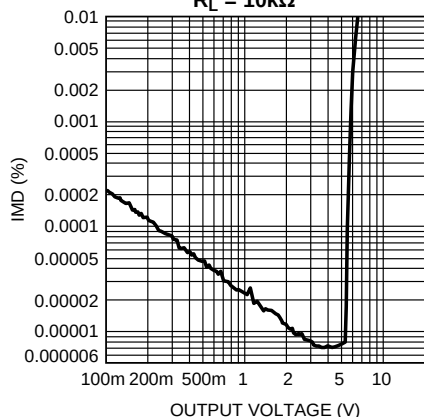


Figure 33.

IMD vs Output Voltage
 $V_{CC} = 22V$, $V_{EE} = -22V$
 $R_L = 10k\Omega$

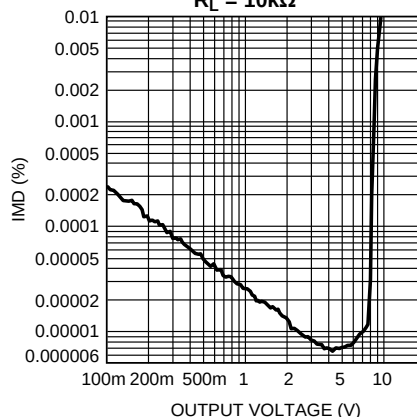


Figure 34.

IMD vs Output Voltage
 $V_{CC} = 2.5V$, $V_{EE} = -2.5V$
 $R_L = 10k\Omega$

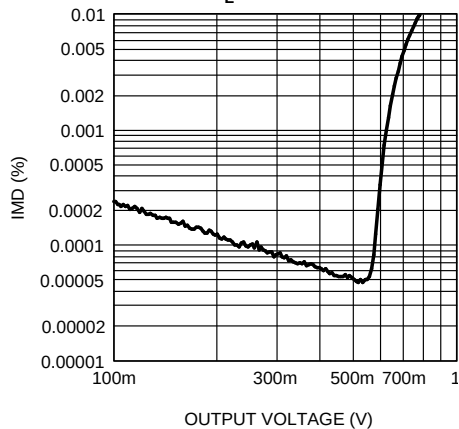


Figure 35.

Voltage Noise Density vs Frequency

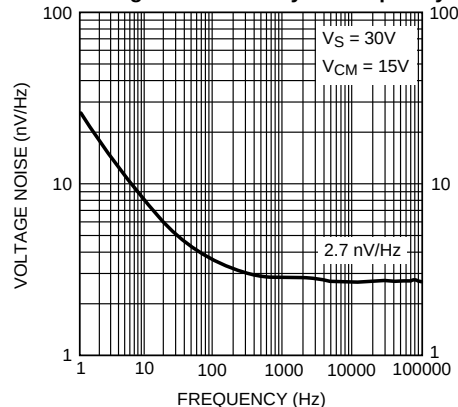


Figure 36.

Current Noise Density vs Frequency

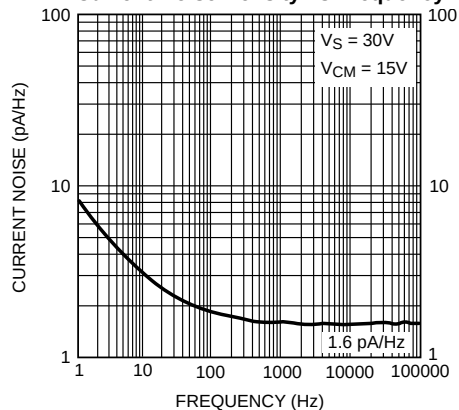


Figure 37.

PSRR+ vs Frequency
 $V_{CC} = 15V$, $V_{EE} = -15V$
 $R_L = 2k\Omega$, $V_{RIPPLE} = 200mV_{pp}$

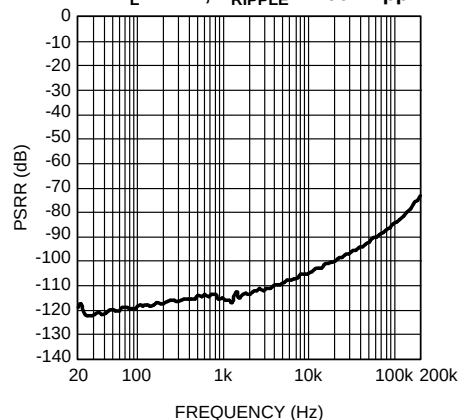


Figure 38.

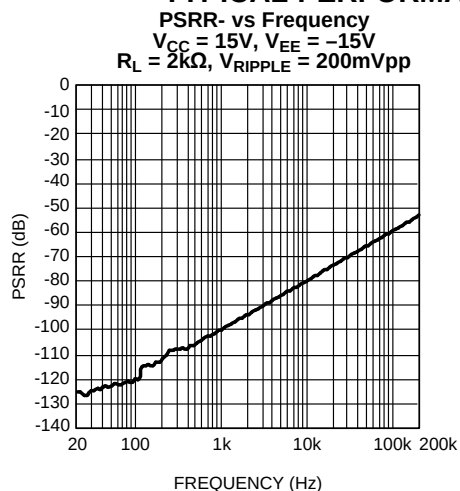
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Figure 39.

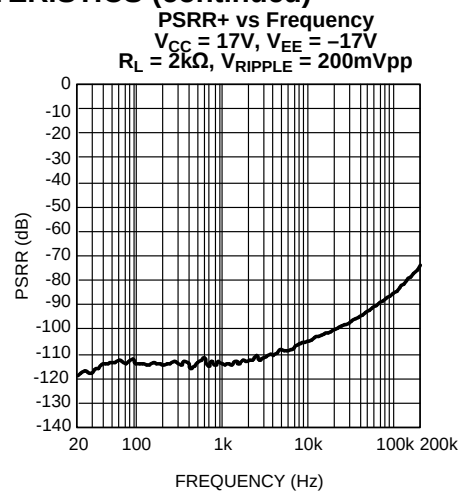


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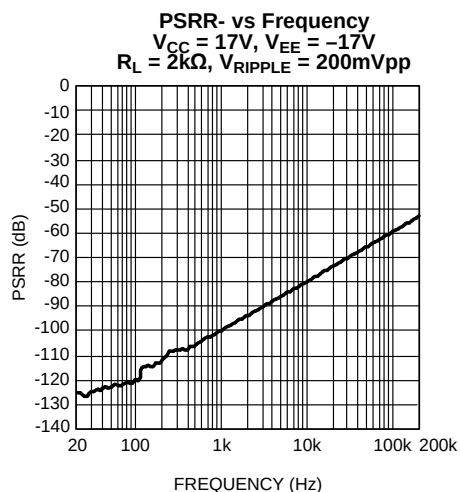


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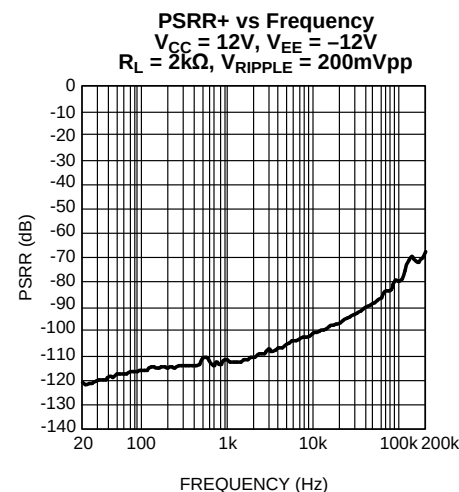


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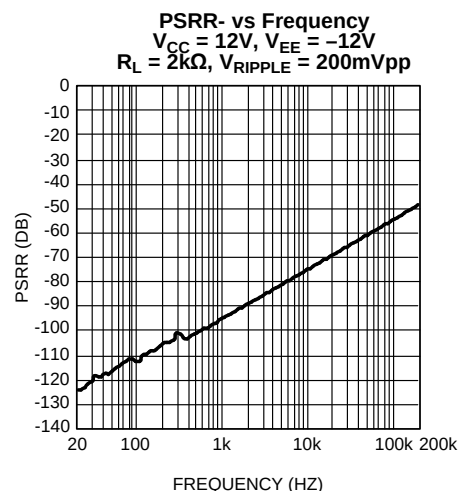


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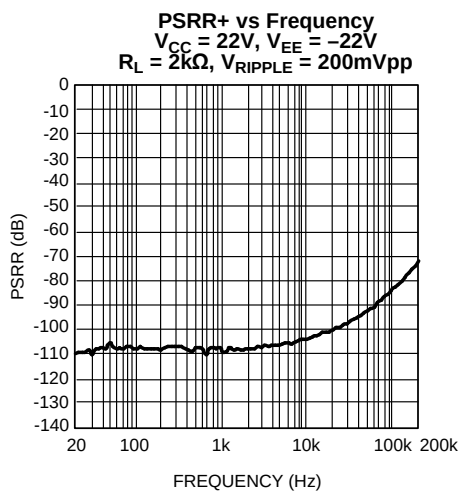


Figure 44.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

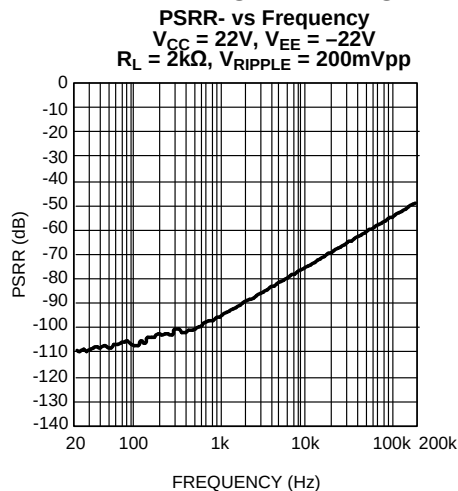


Figure 45.

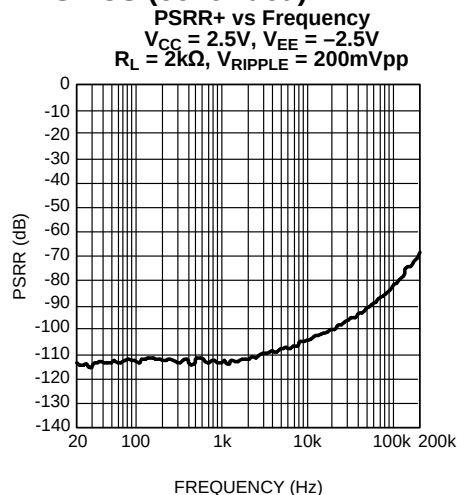


Figure 46.

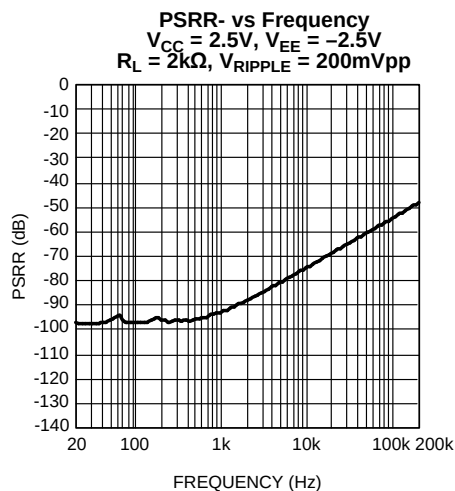


Figure 47.

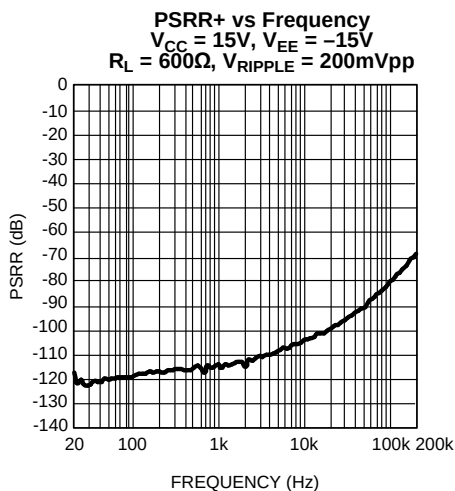


Figure 48.

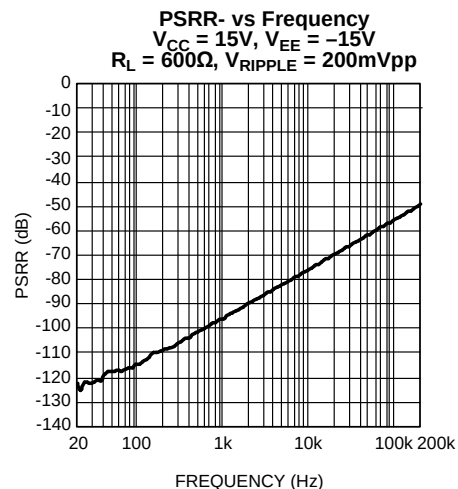


Figure 49.

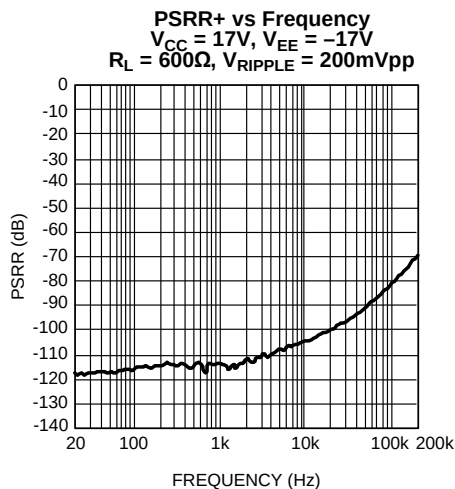


Figure 50.

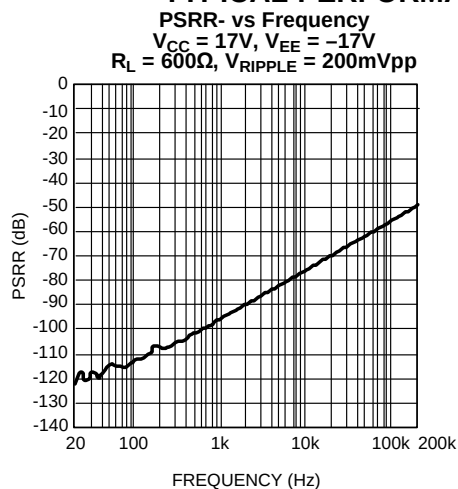
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Figure 51.

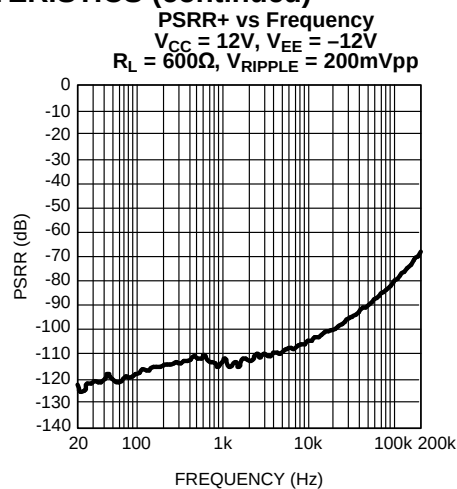


Figure 52.

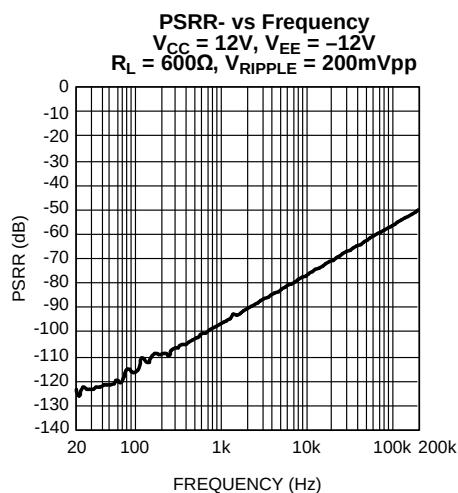


Figure 53.

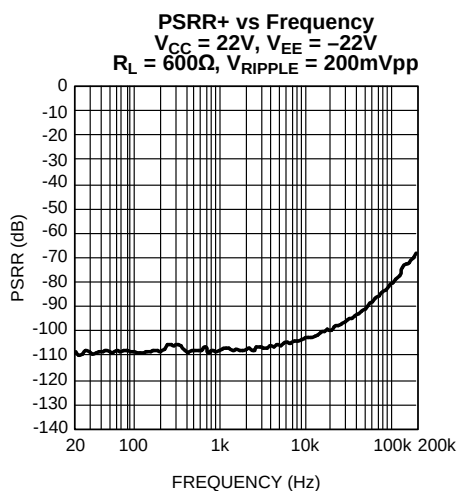


Figure 54.

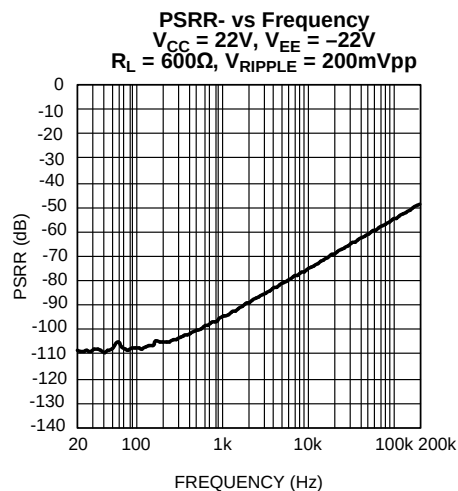


Figure 55.

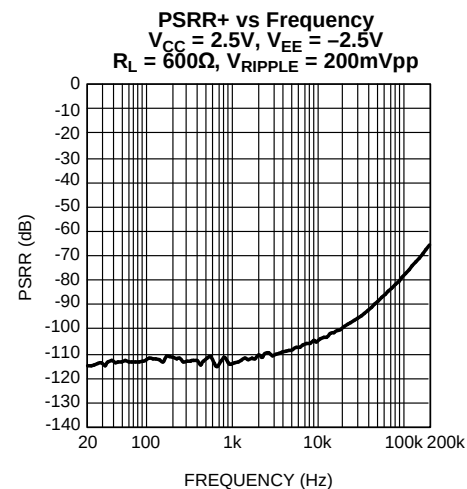


Figure 56.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

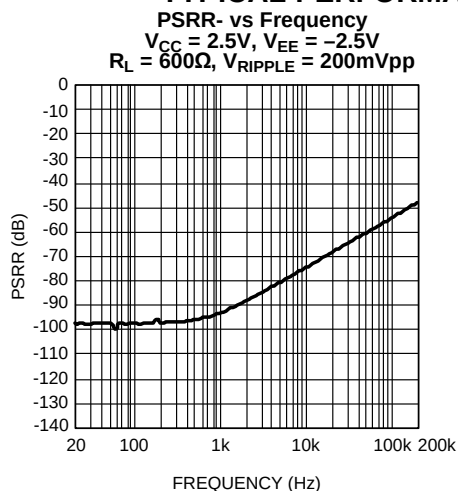


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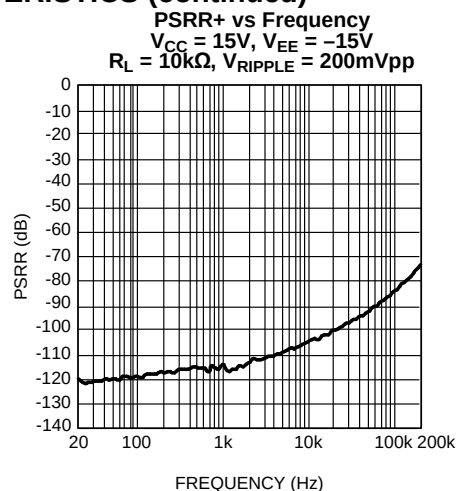


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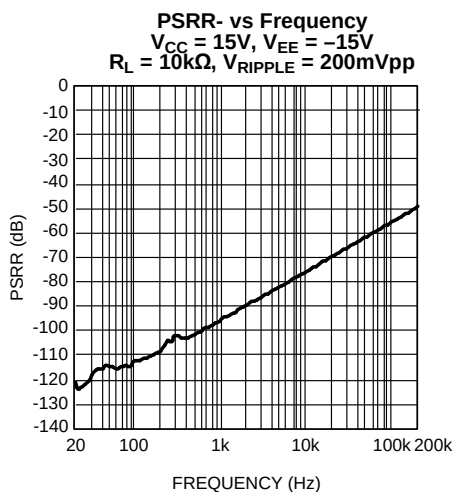


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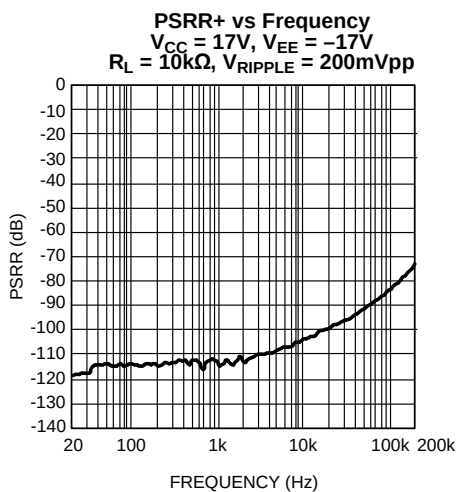


Figure 60.

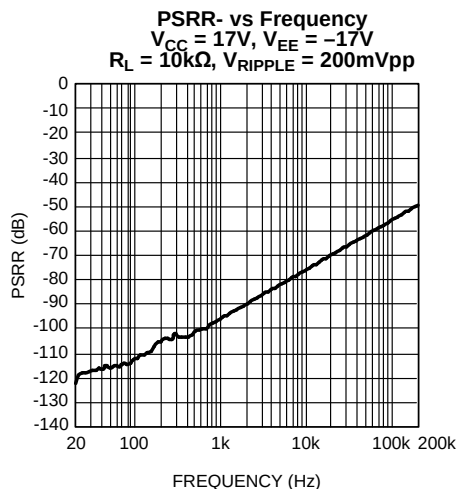


Figure 61.

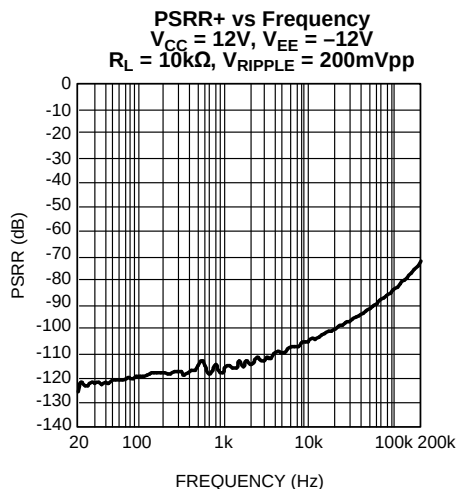


Figure 62.

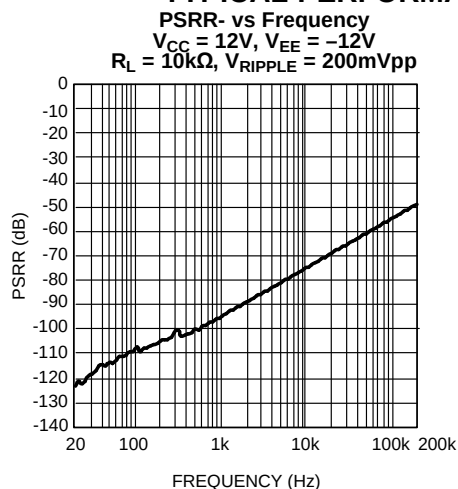
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Figure 63.

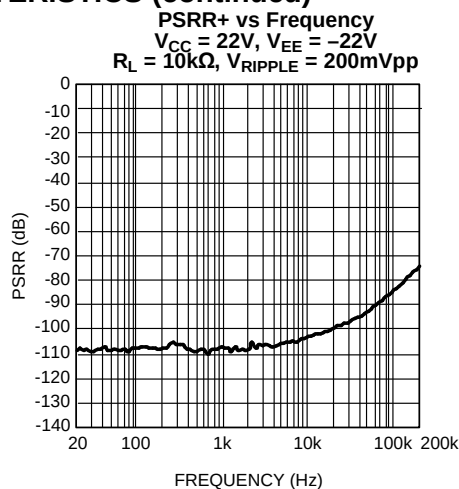


Figure 64.

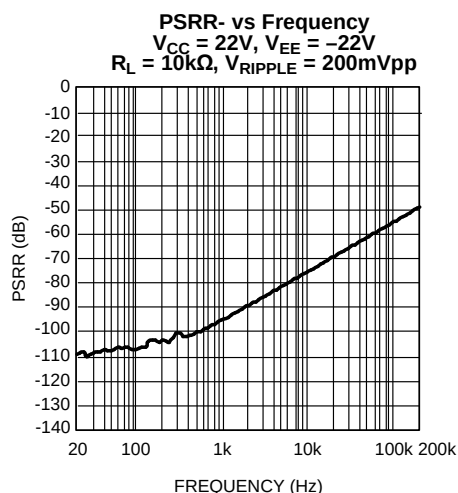


Figure 65.

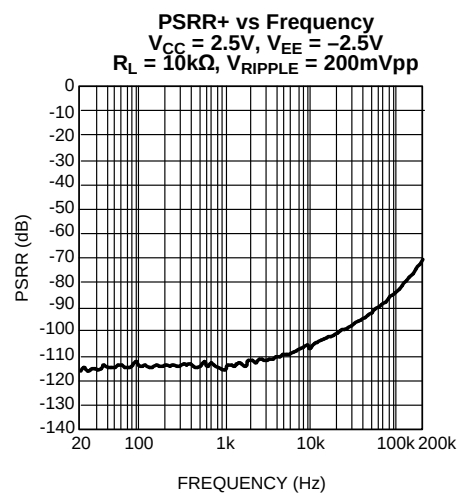


Figure 66.

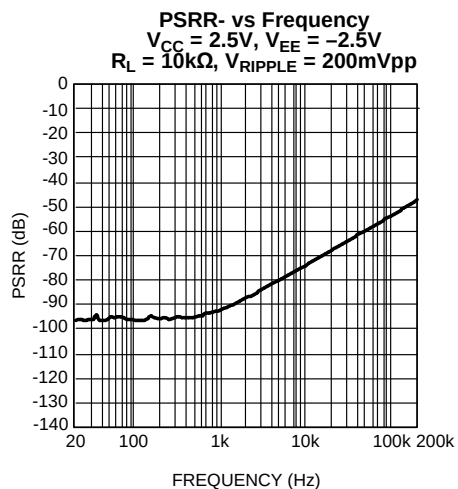


Figure 67.

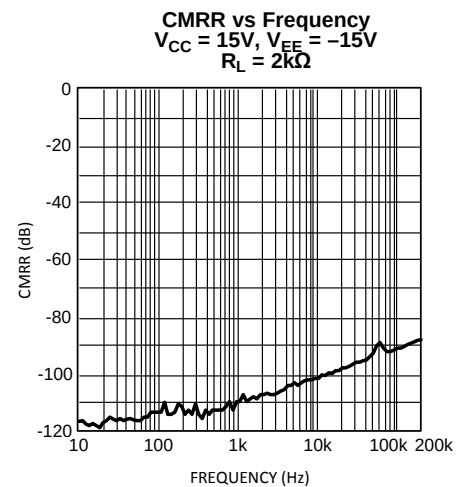


Figure 68.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

CMRR vs Frequency
 $V_{CC} = 12V$, $V_{EE} = -12V$
 $R_L = 2k\Omega$

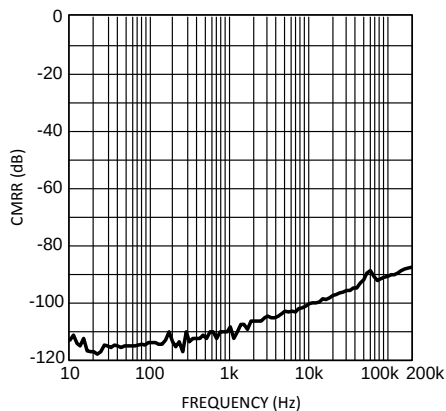


Figure 69.

CMRR vs Frequency
 $V_{CC} = 22V$, $V_{EE} = -22V$
 $R_L = 2k\Omega$

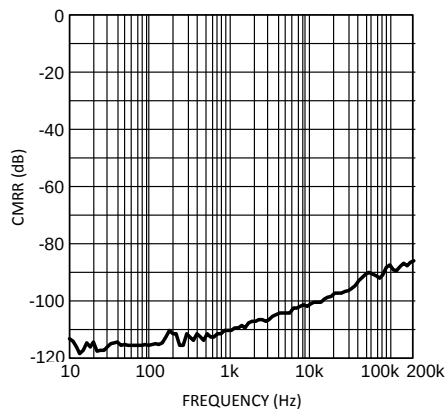


Figure 70.

CMRR vs Frequency
 $V_{CC} = 2.5V$, $V_{EE} = -2.5V$
 $R_L = 2k\Omega$

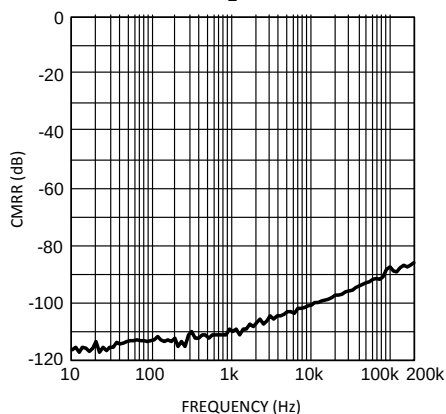


Figure 71.

CMRR vs Frequency
 $V_{CC} = 15V$, $V_{EE} = -15V$
 $R_L = 600\Omega$

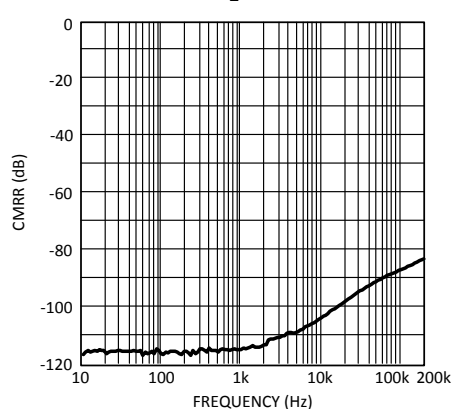


Figure 72.

CMRR vs Frequency
 $V_{CC} = 12V$, $V_{EE} = -12V$
 $R_L = 600\Omega$

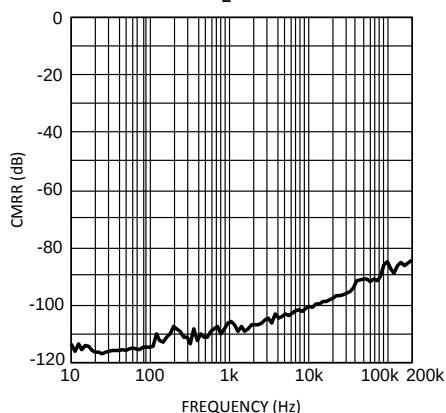


Figure 73.

CMRR vs Frequency
 $V_{CC} = 22V$, $V_{EE} = -22V$
 $R_L = 600\Omega$

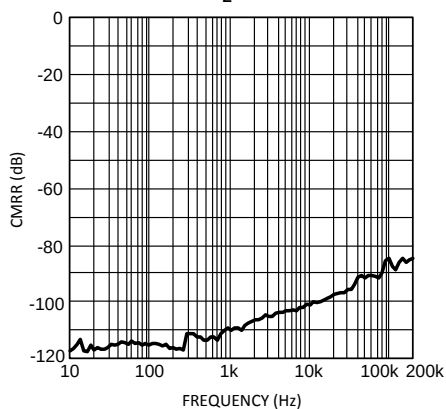
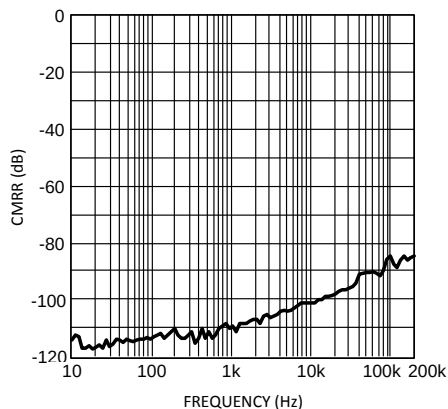


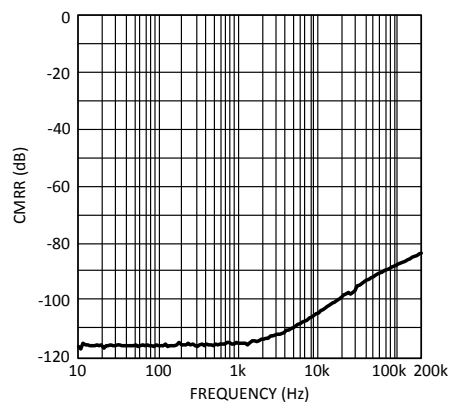
Figure 74.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

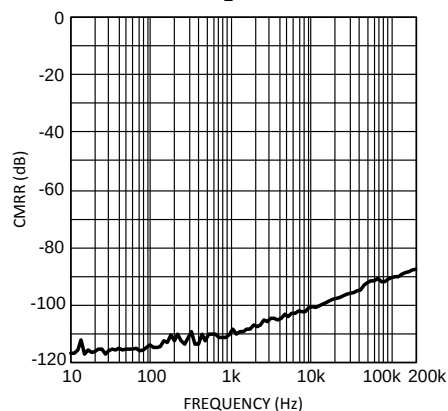
CMRR vs Frequency
 $V_{CC} = 2.5V$, $V_{EE} = -2.5V$
 $R_L = 600\Omega$

**Figure 75.**

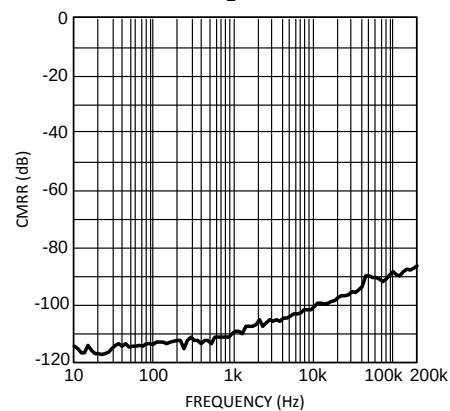
CMRR vs Frequency
 $V_{CC} = 15V$, $V_{EE} = -15V$
 $R_L = 10k\Omega$

**Figure 76.**

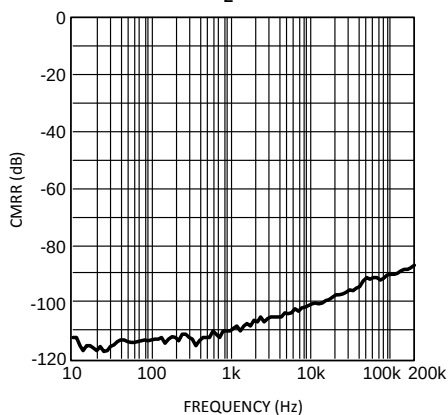
CMRR vs Frequency
 $V_{CC} = 12V$, $V_{EE} = -12V$
 $R_L = 10k\Omega$

**Figure 77.**

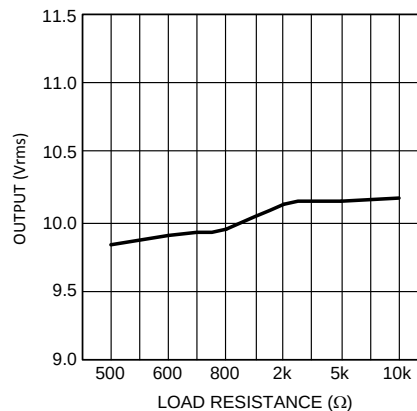
CMRR vs Frequency
 $V_{CC} = 22V$, $V_{EE} = -22V$
 $R_L = 10k\Omega$

**Figure 78.**

CMRR vs Frequency
 $V_{CC} = 2.5V$, $V_{EE} = -2.5V$
 $R_L = 10k\Omega$

**Figure 79.**

Output Voltage vs Load Resistance
 $V_{CC} = 15V$, $V_{EE} = -15V$
 $THD+N = 1\%$

**Figure 80.**

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Output Voltage vs Load Resistance
 $V_{CC} = 12V$, $V_{EE} = -12V$
 $THD+N = 1\%$

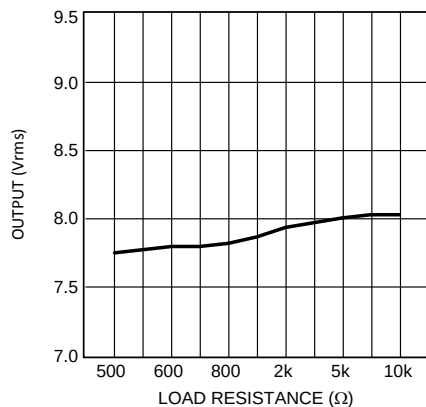


Figure 81.

Output Voltage vs Load Resistance
 $V_{CC} = 22V$, $V_{EE} = -22V$
 $THD+N = 1\%$

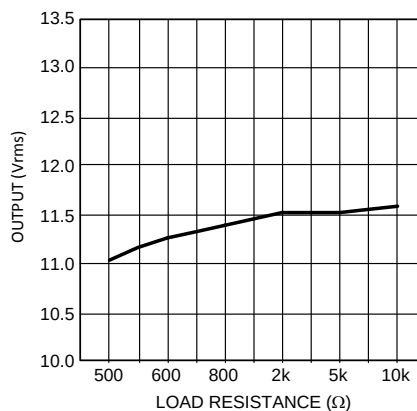


Figure 82.

Output Voltage vs Load Resistance
 $V_{CC} = 2.5V$, $V_{EE} = -2.5V$
 $THD+N = 1\%$

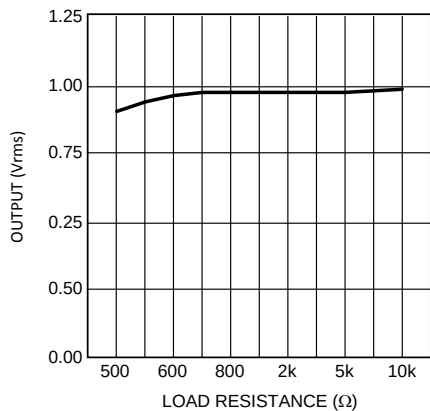


Figure 83.

Output Voltage vs Total Power Supply Voltage
 $R_L = 2k\Omega$, $THD+N = 1\%$

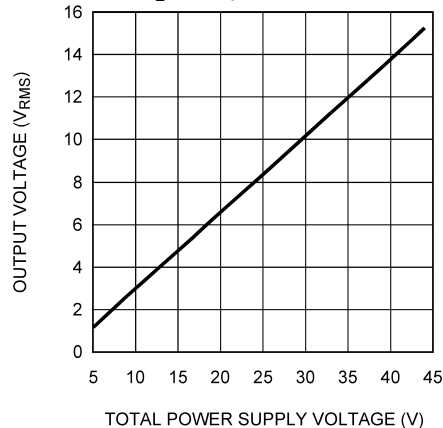


Figure 84.

Output Voltage vs Total Power Supply Voltage
 $R_L = 600\Omega$, $THD+N = 1\%$

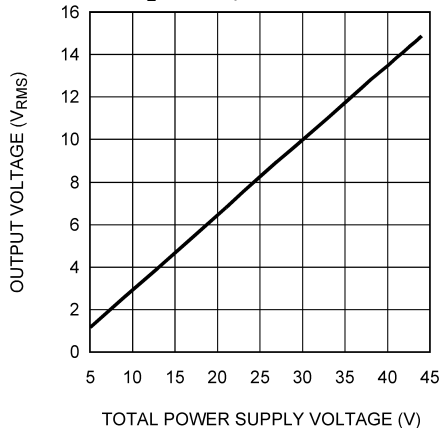


Figure 85.

Output Voltage vs Total Power Supply Voltage
 $R_L = 10k\Omega$, $THD+N = 1\%$

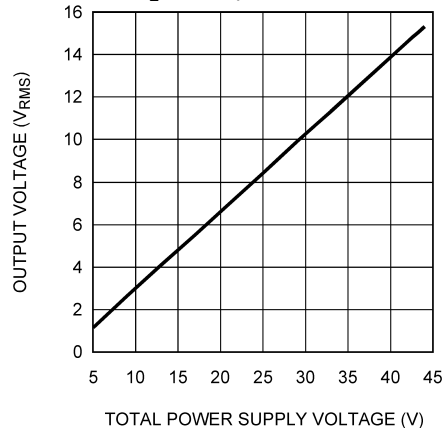


Figure 86.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

**Power Supply Current vs
Total Power Supply Voltage**
 $R_L = 2k\Omega$

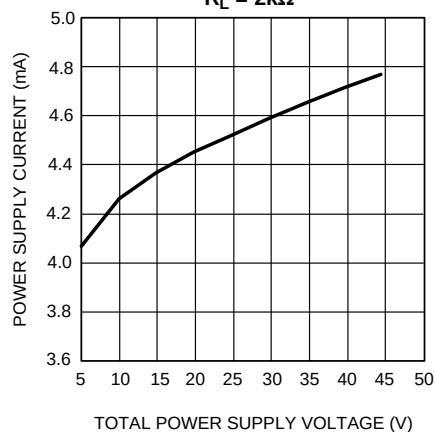


Figure 87.

**Power Supply Current vs
Total Power Supply Voltage**
 $R_L = 600\Omega$

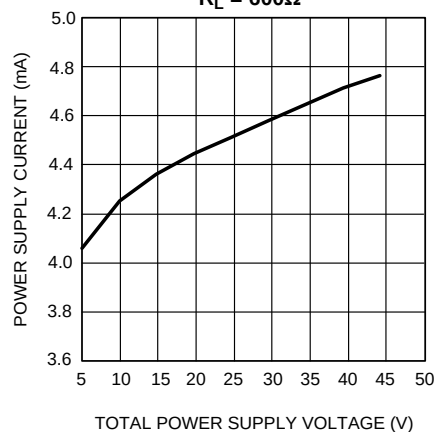


Figure 88.

**Power Supply Current vs
Total Power Supply Voltage**
 $R_L = 10k\Omega$

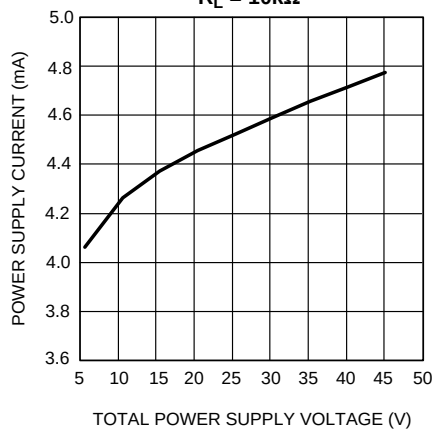


Figure 89.

**Full Power Bandwidth vs
Frequency**
 $V_S = \pm 18V, R_L = 2k\Omega$

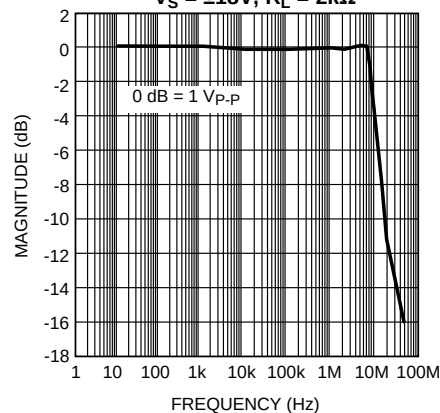


Figure 90.

Gain Phase vs Frequency
 $V_S = \pm 18V, R_L = 2k\Omega$

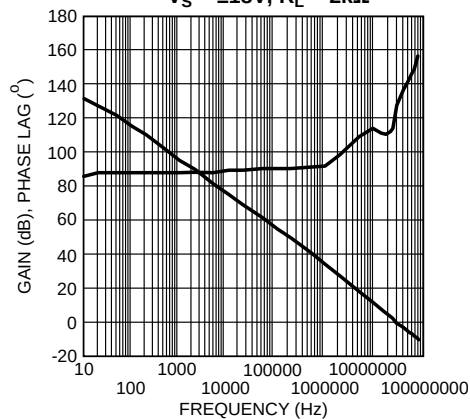


Figure 91.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

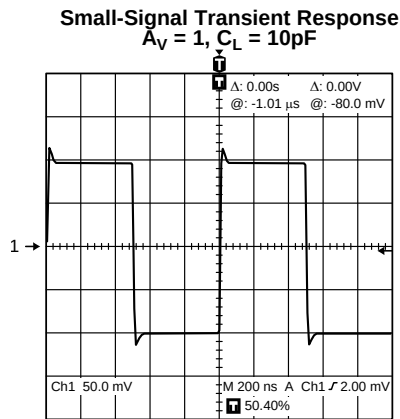


Figure 92.

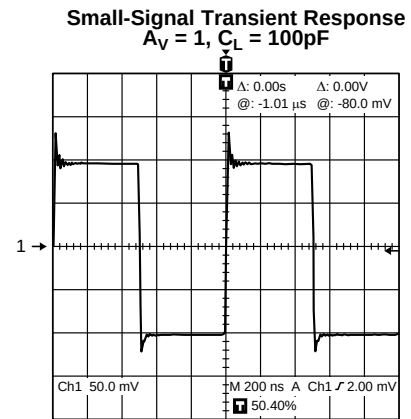


Figure 93.

APPLICATION INFORMATION

DISTORTION MEASUREMENTS

The vanishingly low residual distortion produced by LME49870 is below the capabilities of all commercially available equipment. This makes distortion measurements just slightly more difficult than simply connecting a distortion meter to the amplifier's inputs and outputs. The solution, however, is quite simple: an additional resistor. Adding this resistor extends the resolution of the distortion measurement equipment.

The LME49870's low residual distortion is an input referred internal error. As shown in [Figure 94](#), adding the 10Ω resistor connected between the amplifier's inverting and non-inverting inputs changes the amplifier's noise gain. The result is that the error signal (distortion) is amplified by a factor of 101. Although the amplifier's closed-loop gain is unaltered, the feedback available to correct distortion errors is reduced by 101, which means that measurement resolution increases by 101. To ensure minimum effects on distortion measurements, keep the value of R1 low as shown in [Figure 94](#).

This technique is verified by duplicating the measurements with high closed loop gain and/or making the measurements at high frequencies. Doing so produces distortion components that are within the measurement equipment's capabilities. This datasheet's THD+N and IMD values were generated using the above described circuit connected to an Audio Precision System Two Cascade.

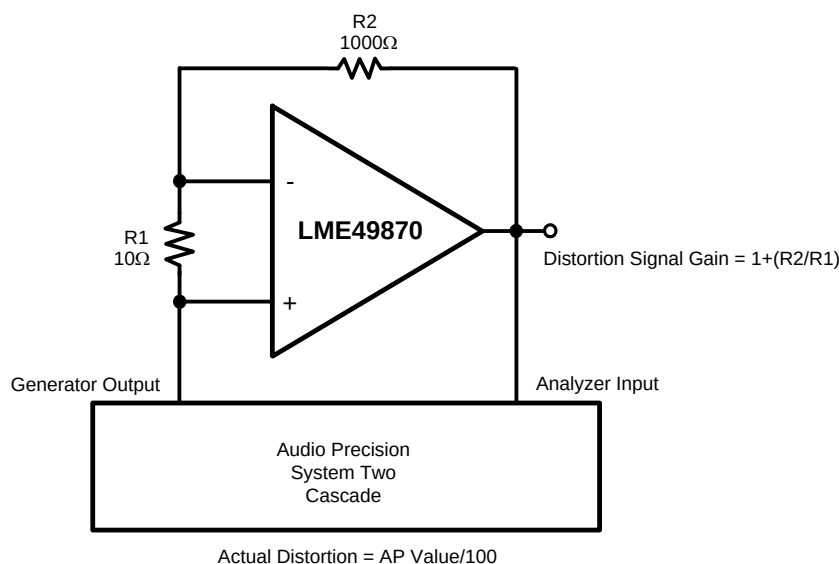
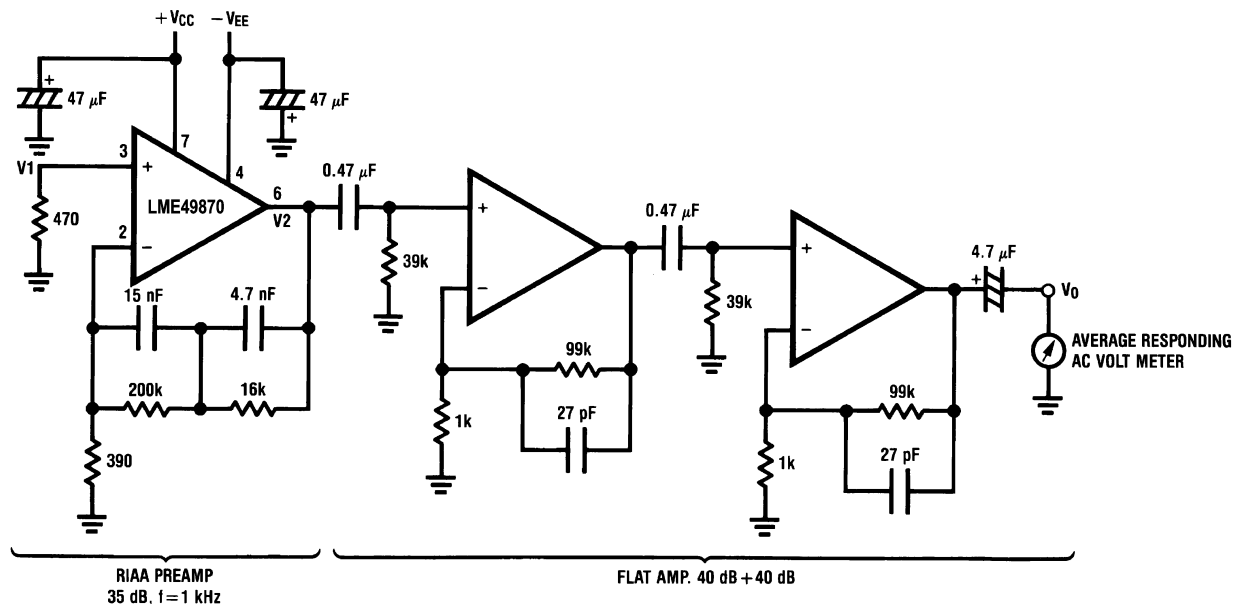


Figure 94. THD+N and IMD Distortion Test Circuit

The LME49870 is a high speed op amp with excellent phase margin and stability. Capacitive loads up to 100pF will cause little change in the phase characteristics of the amplifiers and are therefore allowable.

Capacitive loads greater than 100pF must be isolated from the output. The most straightforward way to do this is to put a resistor in series with the output. This resistor will also prevent excess power dissipation if the output is accidentally shorted.



Complete shielding is required to prevent induced pick up from external sources. Always check with oscilloscope for power line noise.

Figure 95. Noise Measurement Circuit - Total Gain: 115 dB @ $f = 1$ kHz
Input Referred Noise Voltage: $e_n = V_0/560,000$ (V)

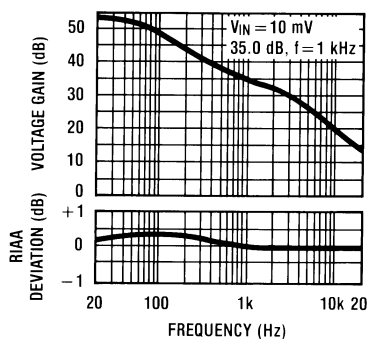


Figure 96. RIAA Preamp Voltage Gain, RIAA Deviation vs Frequency

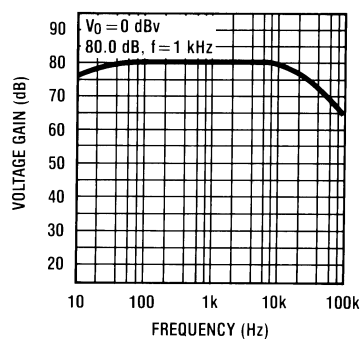
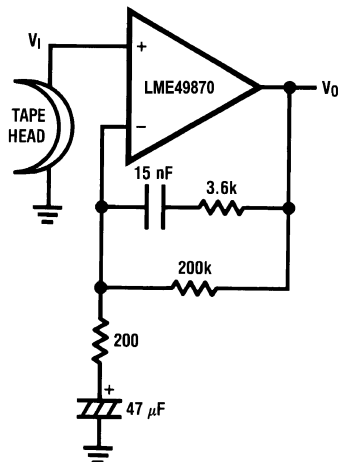


Figure 97. Flat Amp Voltage Gain vs Frequency

TYPICAL APPLICATIONS



$A_V = 34.5$
 $F = 1 \text{ kHz}$
 $E_n = 0.38 \mu\text{V}$
 A Weighted

Figure 98. NAB Preamp

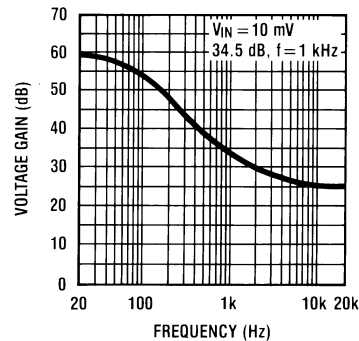
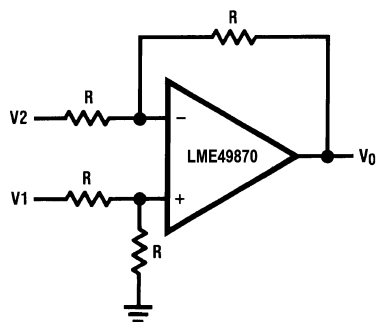
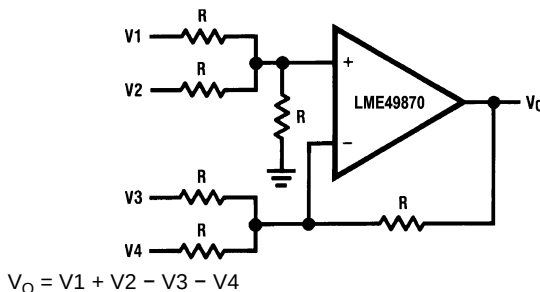


Figure 99. NAB Preamp Voltage Gain vs Frequency



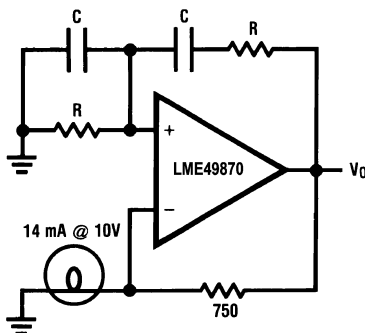
$$V_O = V_1 - V_2$$

Figure 100. Balanced to Single Ended Converter



$$V_O = V_1 + V_2 - V_3 - V_4$$

Figure 101. Adder/Subtractor



$$f_o = \frac{1}{2\pi RC}$$

Figure 102. Sine Wave Oscillator

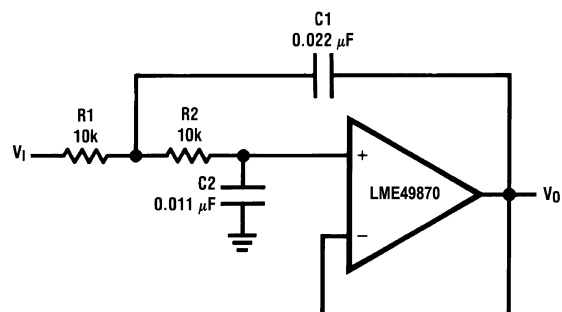
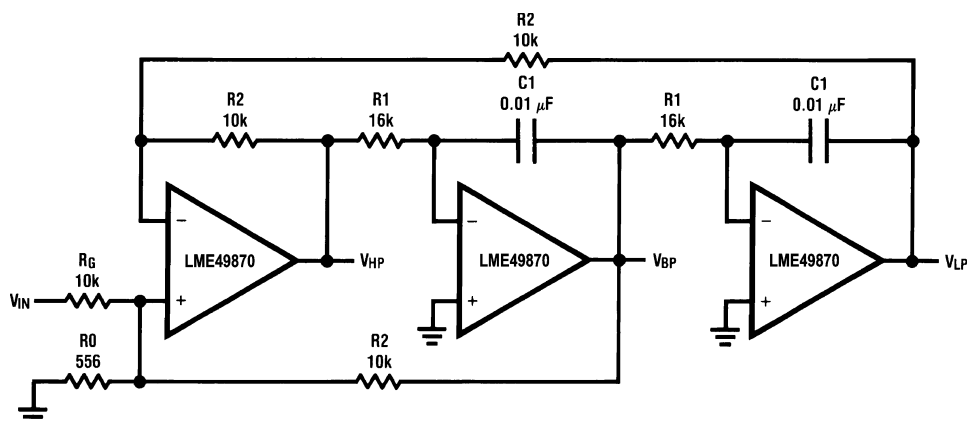


Illustration is $f_0 = 1$ kHz

Figure 104. Second Order Low Pass Filter (Butterworth)



$$f_0 = \frac{1}{2\pi C_1 R_1}, Q = \frac{1}{2} \left(1 + \frac{R_2}{R_0} + \frac{R_2}{R_G} \right), A_{BP} = Q A_{LP} = Q A_{LH} = \frac{R_2}{R_G}$$

Illustration is $f_0 = 1$ kHz, $Q = 10$, $A_{BP} = 1$

Figure 105. State Variable Filter

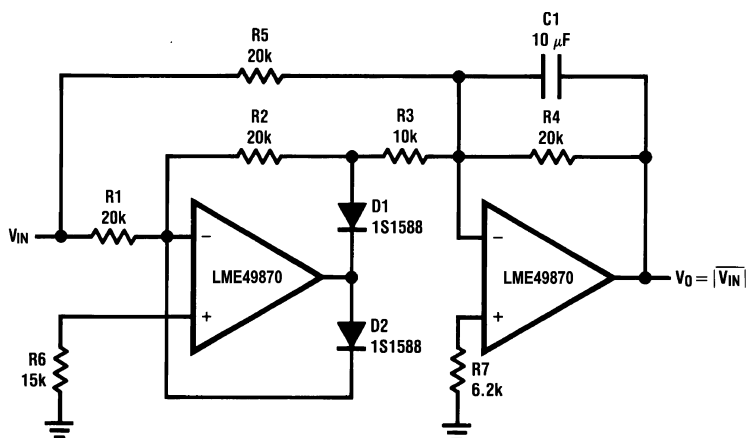


Figure 106. AC/DC Converter

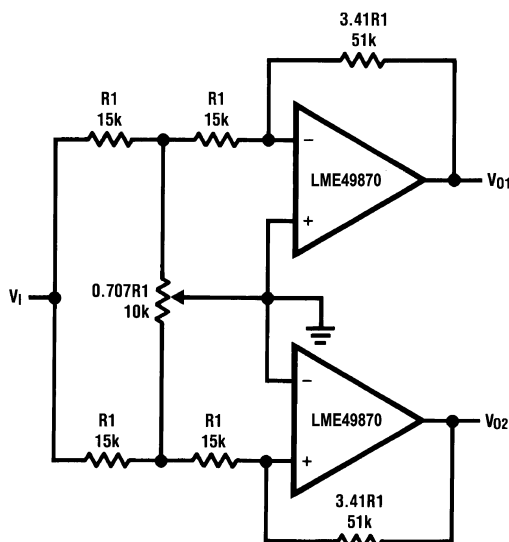


Figure 107. 2 Channel Panning Circuit (Pan Pot)

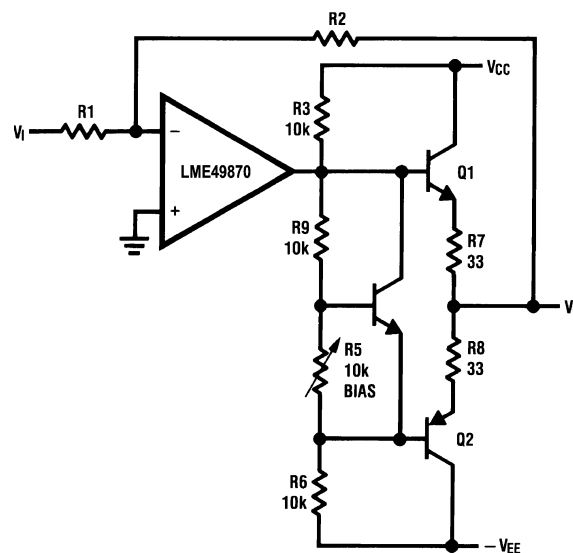
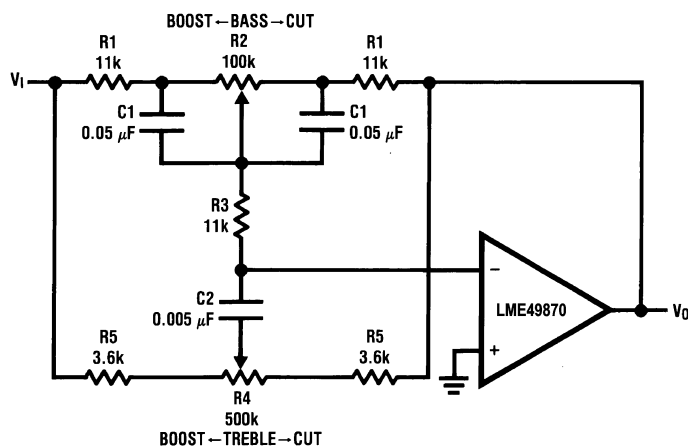


Figure 108. Line Driver



$$f_L = \frac{1}{2\pi R_2 C_1}, f_{LB} = \frac{1}{2\pi R_1 C_1}$$

$$f_H = \frac{1}{2\pi R_5 C_2}, f_{HB} = \frac{1}{2\pi (R_1 + R_5 + 2R_3) C_2}$$

Illustration is:

$$f_L = 32 \text{ Hz}, f_{LB} = 320 \text{ Hz}$$

$$f_H = 11 \text{ kHz}, f_{HB} = 1.1 \text{ kHz}$$

Figure 109.

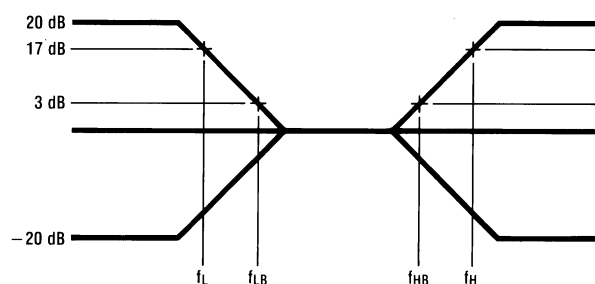
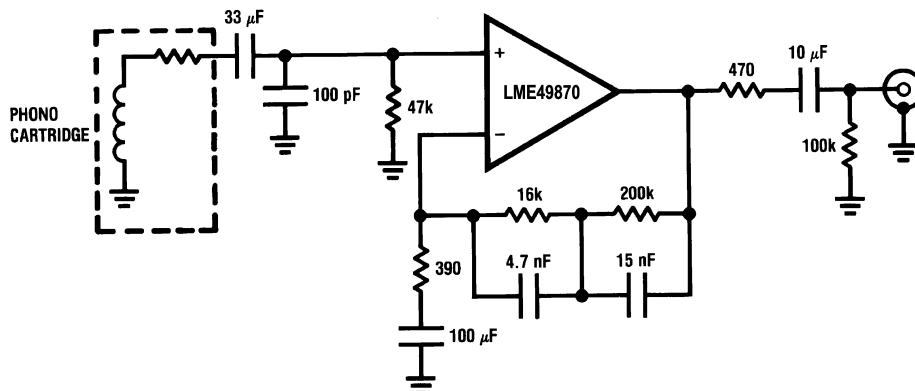
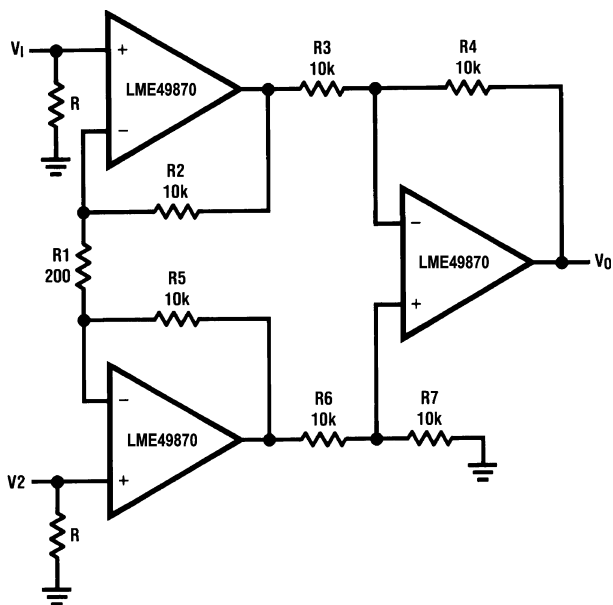


Figure 110. Tone Control



$A_v = 35 \text{ dB}$
 $E_n = 0.33 \text{ } \mu\text{V}$
 $S/N = 90 \text{ dB}$
 $f = 1 \text{ kHz}$
 $A \text{ Weighted}$
 $A \text{ Weighted, } V_{IN} = 10 \text{ mV}$
 $@f = 1 \text{ kHz}$

Figure 111. RIAA Preamp



If $R_2 = R_5$, $R_3 = R_6$, $R_4 = R_7$

$$V_0 = \left(1 + \frac{2R_2}{R_1} \right) \frac{R_4}{R_3} (V_2 - V_1)$$

Illustration is:

$$V_0 = 101(V_2 - V_1)$$

Figure 112. Balanced Input Mic Amp

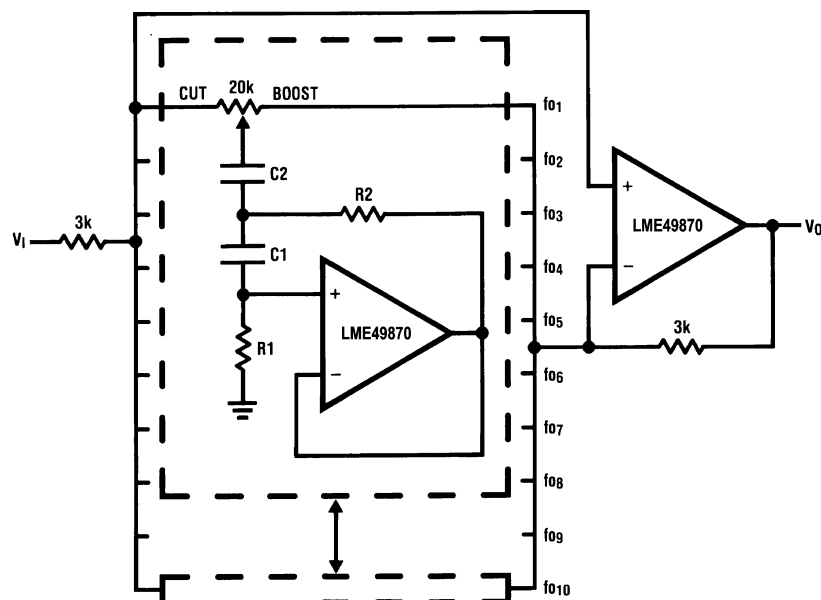


Figure 113. 10 Band Graphic Equalizer

f_o (Hz)	C_1	C_2	R_1	R_2
32	$0.12\mu\text{F}$	$4.7\mu\text{F}$	$75\text{k}\Omega$	500Ω
64	$0.056\mu\text{F}$	$3.3\mu\text{F}$	$68\text{k}\Omega$	510Ω
125	$0.033\mu\text{F}$	$1.5\mu\text{F}$	$62\text{k}\Omega$	510Ω
250	$0.015\mu\text{F}$	$0.82\mu\text{F}$	$68\text{k}\Omega$	470Ω
500	8200pF	$0.39\mu\text{F}$	$62\text{k}\Omega$	470Ω
1k	3900pF	$0.22\mu\text{F}$	$68\text{k}\Omega$	470Ω
2k	2000pF	$0.1\mu\text{F}$	$68\text{k}\Omega$	470Ω
4k	1100pF	$0.056\mu\text{F}$	$62\text{k}\Omega$	470Ω
8k	510pF	$0.022\mu\text{F}$	$68\text{k}\Omega$	510Ω
16k	330pF	$0.012\mu\text{F}$	$51\text{k}\Omega$	510Ω

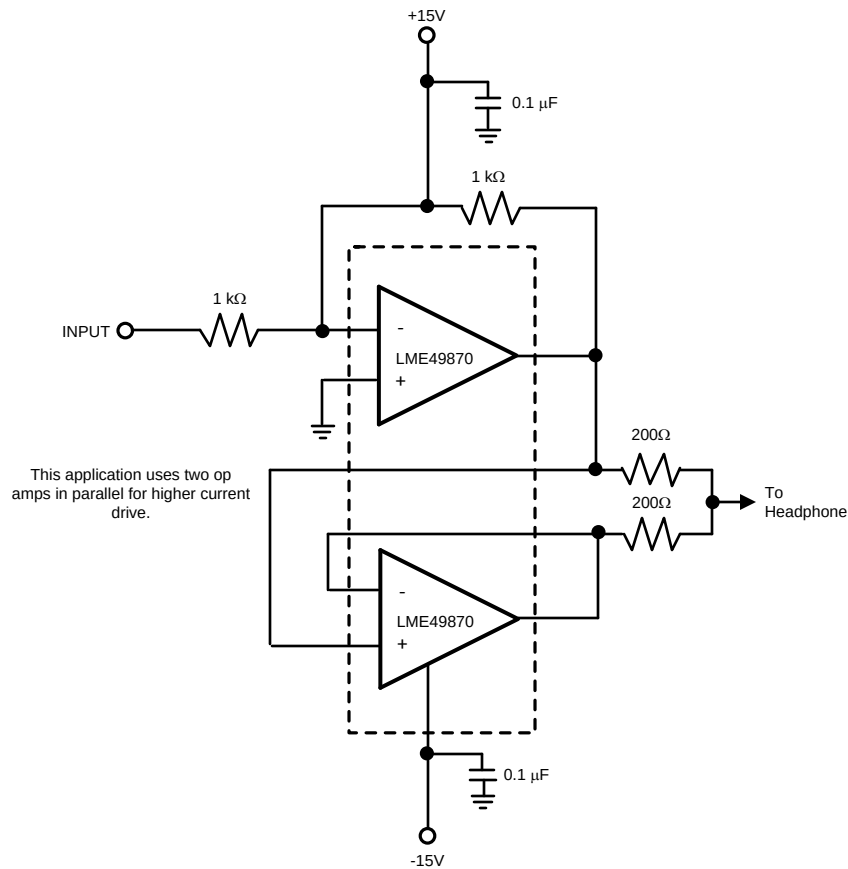


Figure 114. Headphone Amplifier

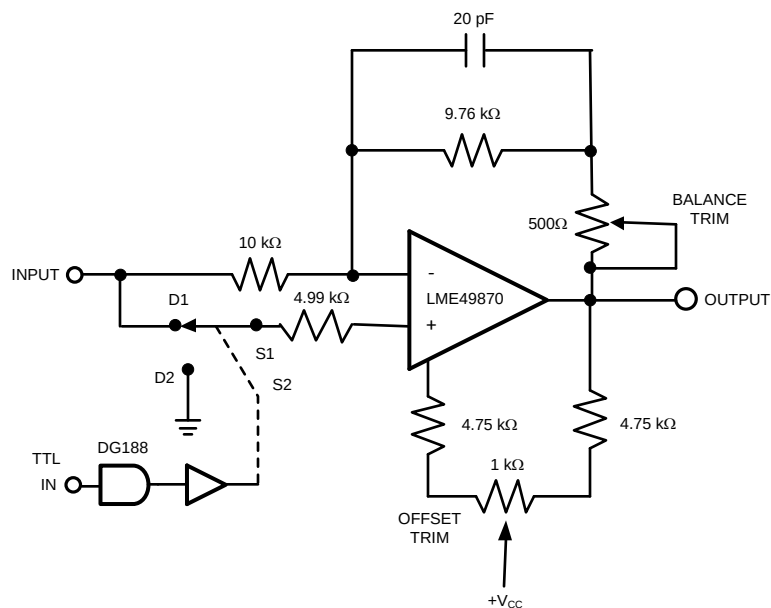
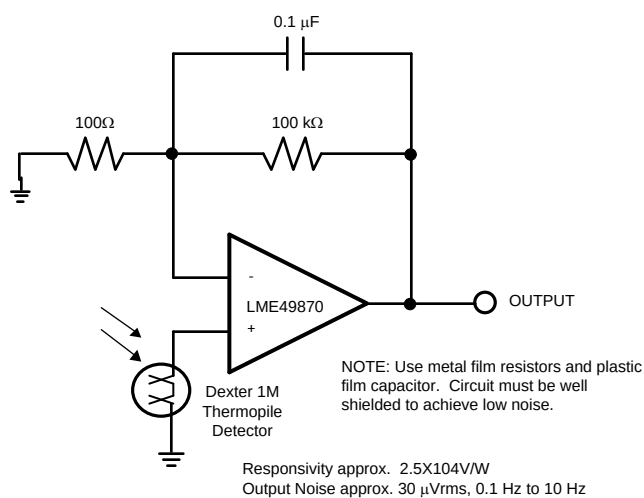


Figure 115. High Performance Synchronous Demodulator

**Figure 116. Long-Wavelength Infrared Detector Amplifier**

REVISION HISTORY

Rev	Date	Description
1.0	09/20/07	Initial release.
1.1	09/27/07	Updated Notes 1–7 (per TI standard).
1.2	12/20/07	Deleted all Crosstalk vs Frequency curves.
1.3	01/14/08	Edited some graphics.
C	04/04/13	Changed layout of National Data Sheet to TI format.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LME49870MA/NOPB	NRND	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	L49870 MA	

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

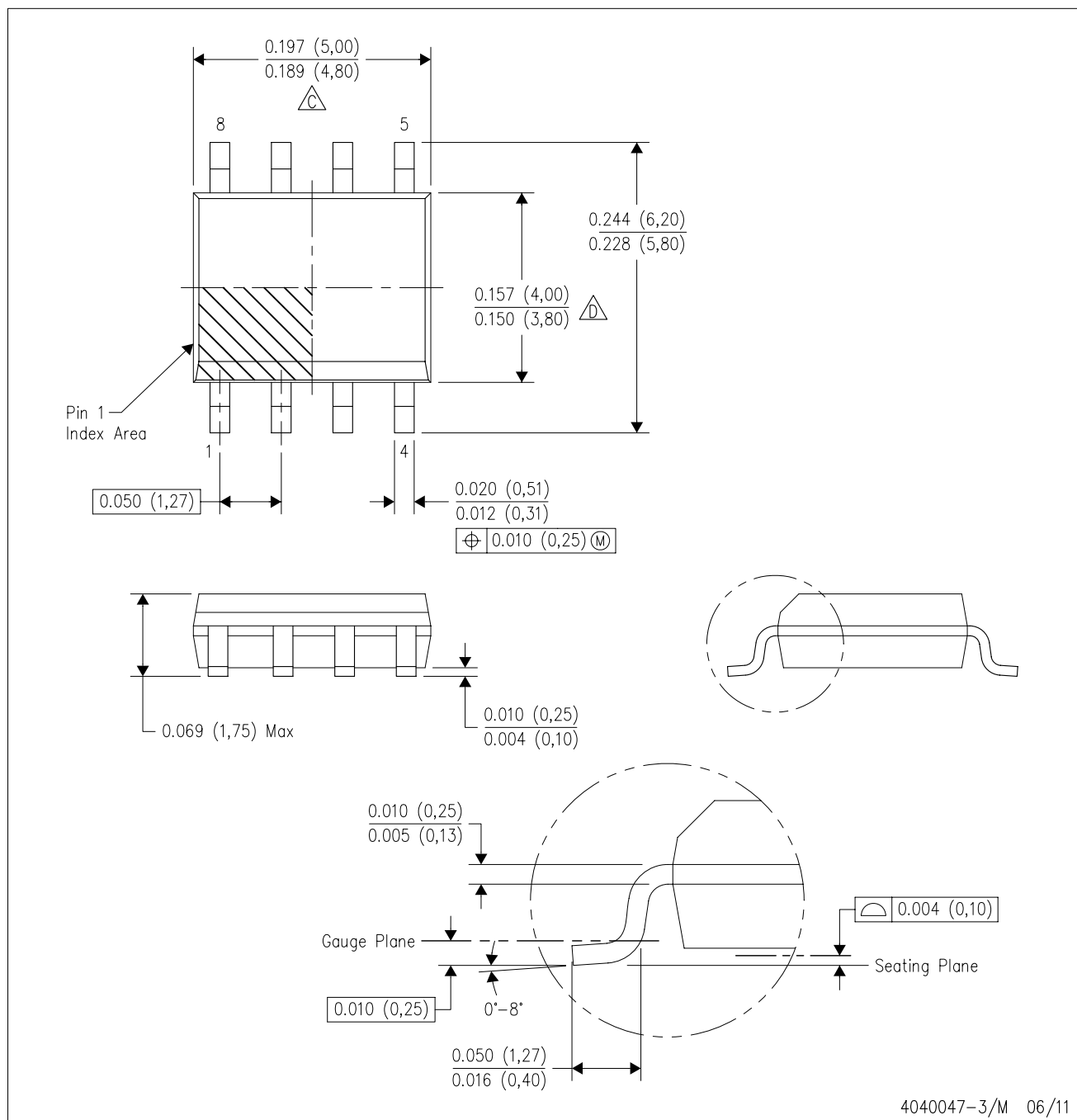
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- $\triangle C$ Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- $\triangle D$ Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AA.

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